X-721-69-517

NASA TM X- 63832

PPM TO ANALOG CONVERTER

DECEMBER 1969

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

X-721-69-517

PPM TO ANALOG CONVERTER

R. J. Stattel
R. K. Kopsidas
R. D. Ceresa
D. L. Harris

Sounding Rocket Instrumentation Section

December 1969

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

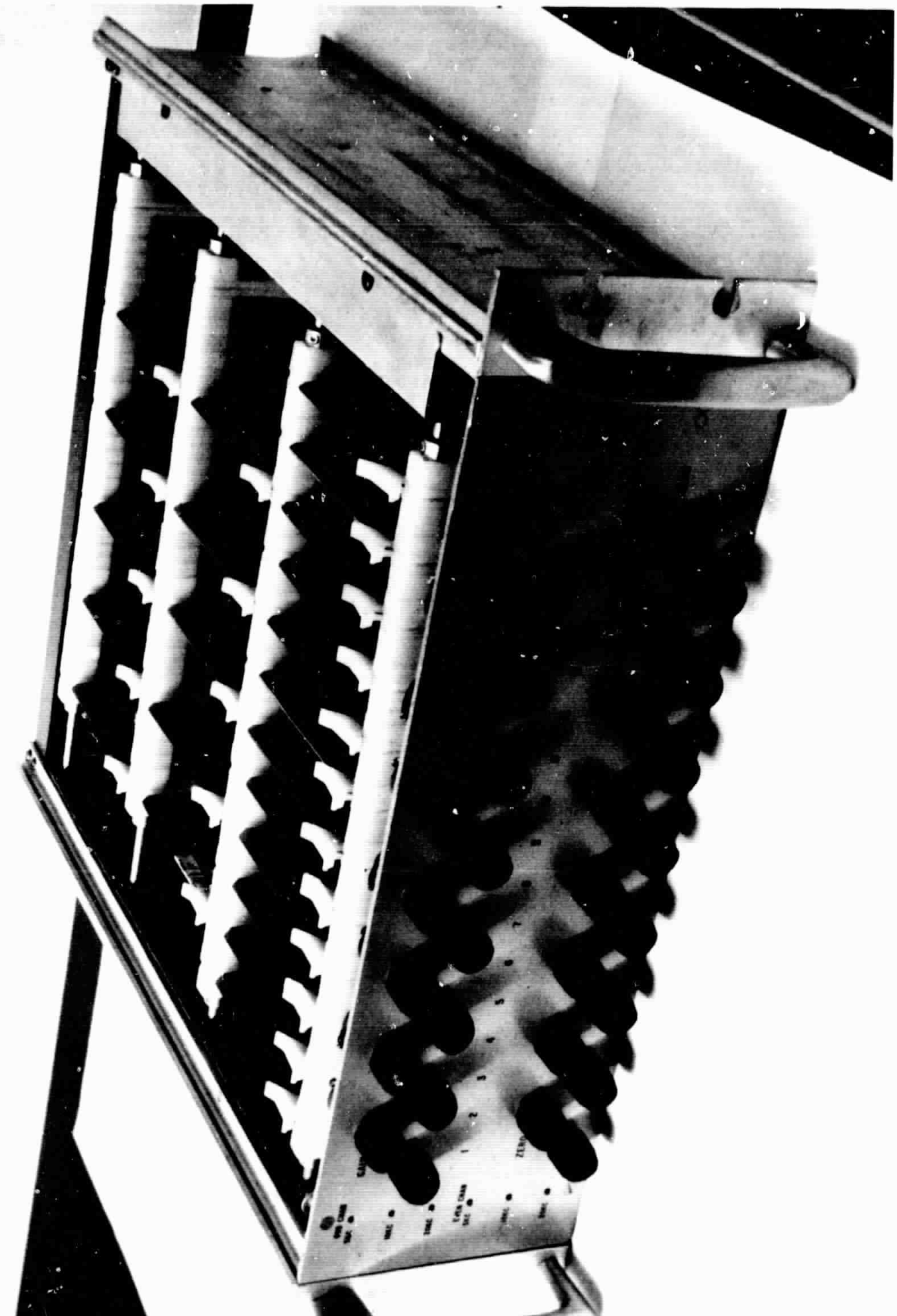
ABSTRACT

The PPM to Analog Converter converts a three-input, pulse-position-modulation (PPM) format, consisting of reference, data, and frame pulses, into sixteen separate analog data channel outputs. These sixteen output channels are fed directly into an analog recorder, which produces an analog readout of the events occurring in each of the sixteen data channels. The PPM to Analog Converter is a part of a PPM telemetry system used extensively for sounding rocket flights. The system was designed by the Sounding Rocket Instrumentation Section of Goddard Space Flight Center.

CONTENTS

ILLUSTRATIONS

TABLES



Frontispiece—PPM to Analog Converter

PPM TO ANALOG CONVERTER

INTRODUCTION

The Sounding Rocket Instrumentation Section of Goddard Space Flight Center has designed and implemented a pulse-position-modulation (PPM) telemetry system which is used extensively for sounding rocket flights. The system serves both for real-time missions in the field, and at the test or assembly station, where the experiments and the rocket instrumentation are integrated and prepared for flight. Figure 1 shows a block diagram of the system.

The PPM telemetry system consists of two major subsystems: the airborne PPM equipment aboard the sounding rocket, and a PPM ground station that receives and records the data transmitted by the airborne system. This report deals exclusively with the PPM to Analog Converter of the PPM ground station, and provides general functional and physical information, theory of operation, operating instructions, and maintenance procedures.

GENERAL INFORMATION

FUNCTIONAL DESCRIPTION

The PPM to Analog Converter converts the three-input PPM format (reference, data, frame) into 16 separate analog channel outputs. These 16 output channels are fed directly into an analog recorder which produces an analog readout paper record of the events occurring in each of the 16 data channels. Thus, the PPM to Analog Converter, together with the analog recorder, comprise a converting and recording system, which can provide the ground station user with real-time quick-readout of all telemetry channels.

Table 1 is provided for general reference. It outlines the important characteristics of the PPM format, reference, data, and frame pulses.

These input pulses can come from any one of four different sources in the PPM ground station: the Simulator, the Servo Clock, the Analog to PPM Converter, or the Tape Electronics circuitry.

PHYSICAL DESCRIPTION

The PPM to Analog Converter is mounted in a standard 19-inch rack assembly, which is normally located near an analog recorder, in a PPM ground

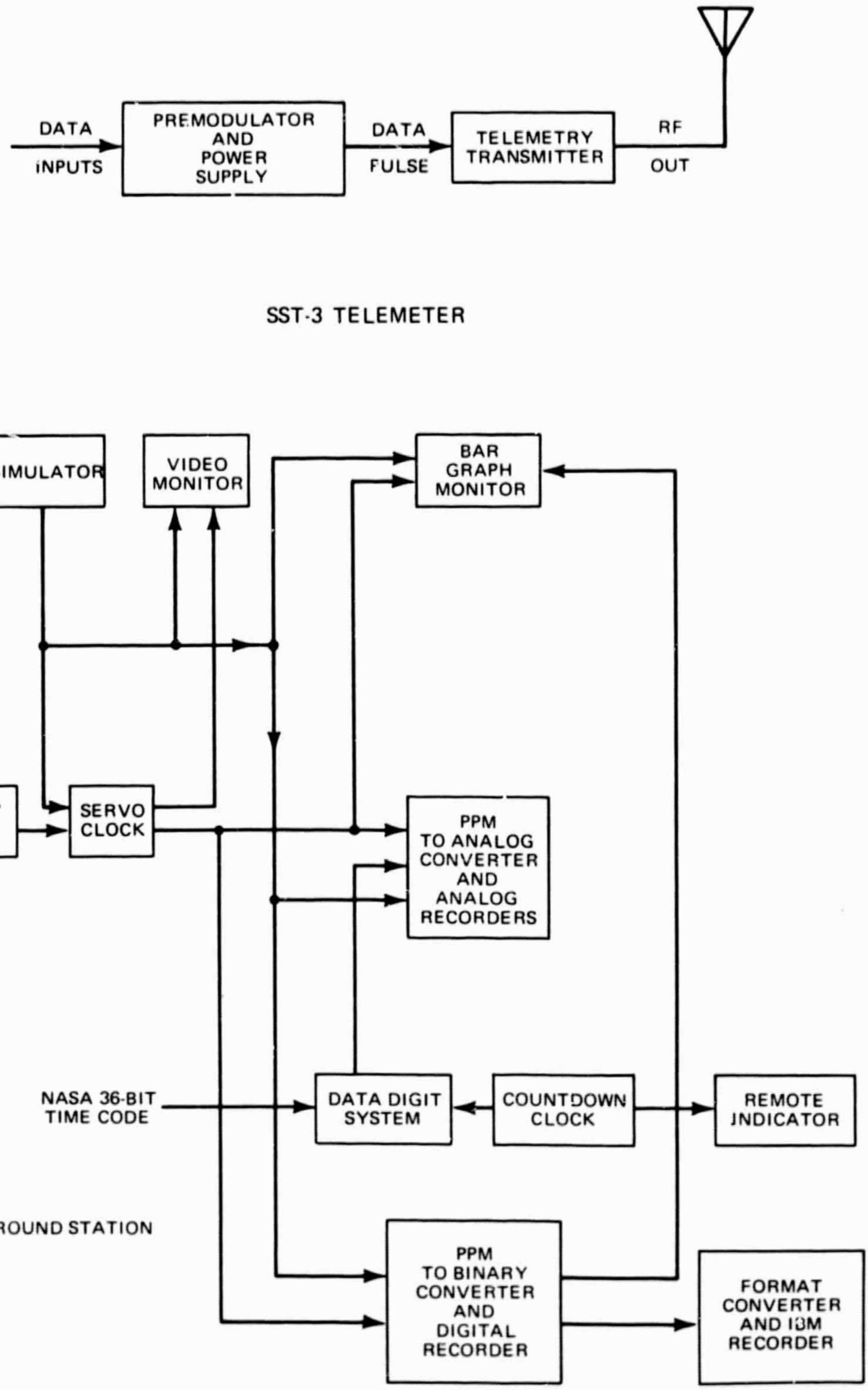


Figure 1. PPM Telemetry System, Functional Block Diagram

Table 1
PPM Format Characteristics

System Clock Rate	Pulse Name	Pulse Voltage	Nominal Pulse Width	Spacing Between Pulses
5 kHz	Ref	Neg. going 0v to -10v	4 μ sec	200 μ sec
	Data	Pos. going 0v to +10v	4 μ sec	350 μ sec max. 50 μ sec min.
	Frame	Neg. going 0v to -10v	4 μ sec	3.2 msec
10 kHz	Ref	Neg. going 0v to -10v	4 μ sec	100 μ sec
	Data	Pos. going 0v to +10v	4 μ sec	175 μ sec max. 25 μ sec min.
	Frame	Neg. going 0v to -10v	4 μ sec	1.6 msec
20 kHz	Ref	Neg. going 0v to -10v	4 μ sec	50 μ sec
	Data	Pos. going 0v to +10v	4 μ sec	87.5 μ sec max. 12.5 μ sec min.
	Frame	Neg. going 0v to -10v	4 μ sec	0.8 msec

station. See Figure 2. The overall dimensions of the PPM to Analog Converter are 19 inches wide by 21 inches deep by 5-1/2 inches high. The weight is approximately 20 pounds and the volume is approximately 2,200 cubic inches.

CAPABILITIES AND LIMITATIONS

Power Requirement:	less than 28 watts from a +3, -3, +10, -10 volt d.c. power supply.
Operating Temperature Range:	+15 degrees C to +55 degrees C (+59 degrees F to +131 degrees F)
Inputs:	PPM format (see Table 1)
Outputs:	16 analog channels

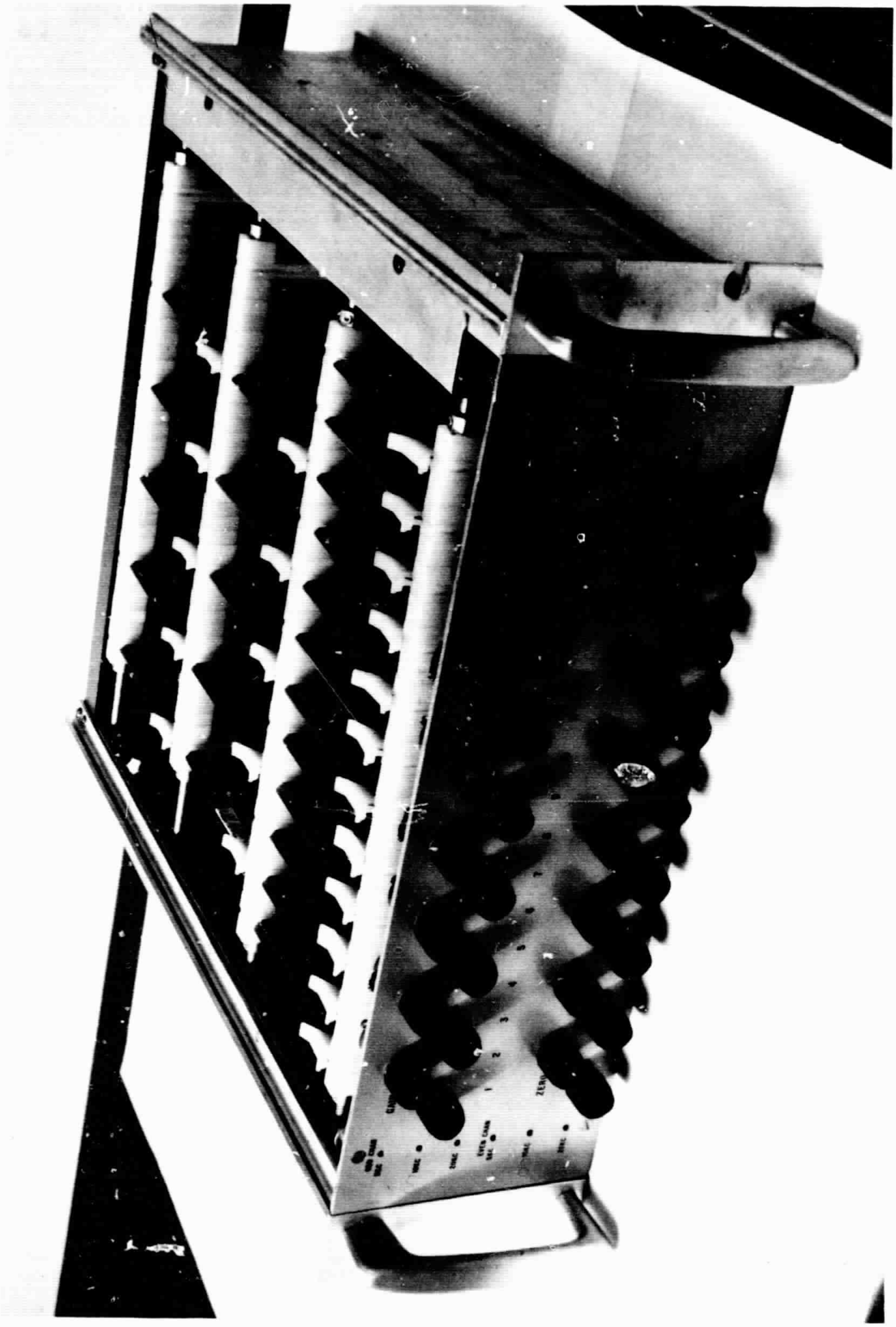


Figure 2. PPM to Analog Converter, Physical Details

THEORY OF OPERATION

Refer to the block diagrams of the PPM to Analog Converter, Figure 3 and Figure 4, sheets 1 and 2. The reference pulse starts a binary counter, consisting of flip-flops FF1 through FF4, which counts from 1 to 16. The frame pulse is used to reset the counter to synchronize it with the airborne system. Flip-flop FF1 generates the low bits 2^0 and $2^{\overline{0}}$,* FF2 generates 2^1 and $2^{\overline{1}}$, FF3 generates 2^2 and $2^{\overline{2}}$, and FF4 generates 2^3 and $2^{\overline{3}}$. The first two bits, 2^0 and $2^{\overline{0}}$, with the data line, are used to generate the timing and gating signals, and to separate the 16 channels into eight odd and eight even channels.

The gating signals are in pulse-duration-modulation (PDM) format, which is used to start and stop the ramp generator of the integrator circuits. The outputs of the integrators are read by the sample-and-hold circuits. See Figures 5 and 6. The two PDM formats, one for odd channels and one for even channels, start the linear ramp generators at the odd and even reference pulses, and terminate the ramp function at the data pulse of each channel. The maximum level reached by the ramp generators is maintained through the remainder of the channel, and also through the following channel until the occurence of the next odd or even reference pulse.

Separation of channels from serial format to parallel format takes place at the diode matrix. Each channel comes out as a separate pulse. A detailed analysis follows. Inputs to the matrix are the eight bits from the counter; namely 2^0, $2^{\overline{0}}$, 2^1, $2^{\overline{1}}$, 2^2, $2^{\overline{2}}$, 2^3, and $2^{\overline{3}}$.* Thus:

$2^0\ 2^{\overline{1}}\ 2^{\overline{2}}\ 2^{\overline{3}}$ is 0001 which is Channel 1

$2^{\overline{0}}\ 2^1\ 2^{\overline{2}}\ 2^{\overline{3}}$ is 0010 which is Channel 2

$2^0\ 2^1\ 2^{\overline{2}}\ 2^{\overline{3}}$ is 0011 which is Channel 3

$2^{\overline{0}}\ 2^{\overline{1}}\ 2^2\ 2^{\overline{3}}$ is 0100 which is Channel 4

$2^0\ 2^{\overline{1}}\ 2^2\ 2^{\overline{3}}$ is 0101 which is Channel 5

$2^{\overline{0}}\ 2^1\ 2^2\ 2^{\overline{3}}$ is 0110 which is Channel 6

$2^0\ 2^1\ 2^2\ 2^{\overline{3}}$ is 0111 which is Channel 7

*Overlines denote inversion.

$2^{\bar{0}}\ 2^{\bar{1}}\ 2^{\bar{2}}\ 2^{3}$ is 1000 which is Channel 8

$2^{0}\ 2^{\bar{1}}\ 2^{\bar{2}}\ 2^{3}$ is 1001 which is Channel 9

$2^{\bar{0}}\ 2^{1}\ 2^{\bar{2}}\ 2^{3}$ is 1010 which is Channel 10

$2^{0}\ 2^{1}\ 2^{\bar{2}}\ 2^{3}$ is 1011 which is Channel 11

$2^{\bar{0}}\ 2^{\bar{1}}\ 2^{2}\ 2^{3}$ is 1100 which is Channel 12

$2^{0}\ 2^{\bar{1}}\ 2^{2}\ 2^{3}$ is 1101 which is Channel 13

$2^{\bar{0}}\ 2^{1}\ 2^{2}\ 2^{3}$ is 1110 which is Channel 14

$2^{0}\ 2^{1}\ 2^{2}\ 2^{3}$ is 1111 which is Channel 15

$2^{\bar{0}}\ 2^{\bar{1}}\ 2^{\bar{2}}\ 2^{\bar{3}}$ is 0000 which is Channel 16

NOTE

"0" bit is a positive pulse and "1" bit is a negative pulse.

The output of the diode matrix consists of 16 parallel lines, each line representing one channel. See Figure 4. The output channel pulse is a positive pulse that lasts for the duration of the channel. Each of these channels is gated by a 30-microsecond pulse that starts at every reference pulse, thus making the duration of the channel pulse 30 microseconds. Each of the 16 gates receives a channel pulse and a 30 microsecond gating pulse. The parallel format output of these gates consists of 16 pulses of 30 microseconds duration each.

The two outputs of the integrators, together with all 16-channel pulses, enter the sample-and-hold circuits. The channel pulses command each sample-and-hold circuit to sample the part of the serial analog signal that is present at the time. A 30 microsecond channel pulse permits sampling of the analog voltage of the previous channel. See Figure 5. The sample-and-hold outputs are the desired 16-channel parallel format analog voltages.

The 16 channels of analog voltage feed the galvanometer driver-amplifiers, which in turn drive the galvanometers of the analog recorder. Two additional amplifiers are used in the system to drive the two time-code formats (the 36 and 28-bit NASA time codes, referred to on Figures 3 and 4 as T1 and T2, respectively). Deflections of the galvanometers are proportional and linear to the analog voltage and the photosensitive paper of the analog recorder provides the visual readout of the 16-channel analog voltages.

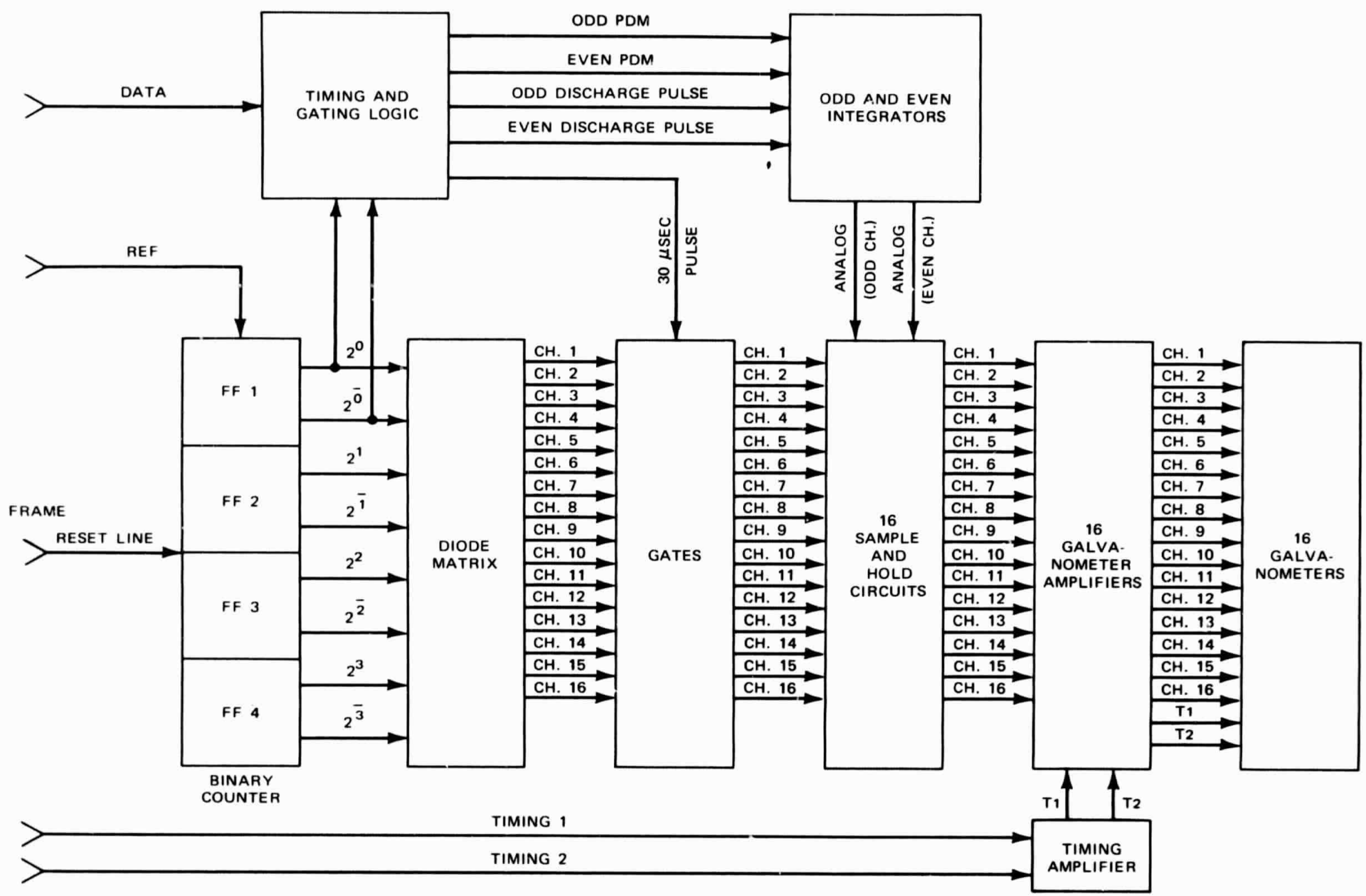
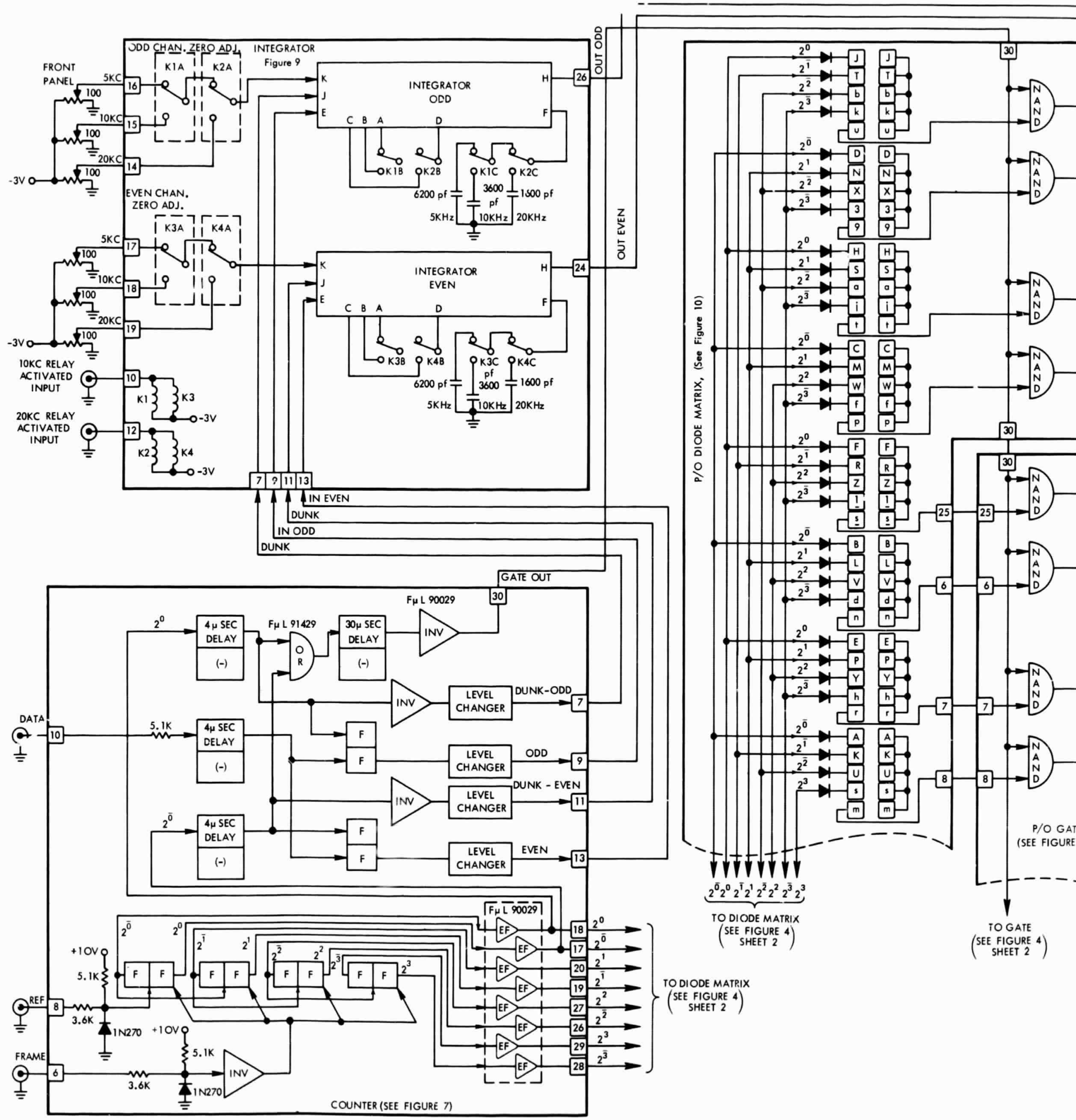


Figure 3. PPM to Analog Converter, Simplified Block Diagram

PRECEDING PAGE BLANK NOT FILMED.



NOTE:
All diodes on Diode Matrix are 1N798

FOLDOUT FRAME 1

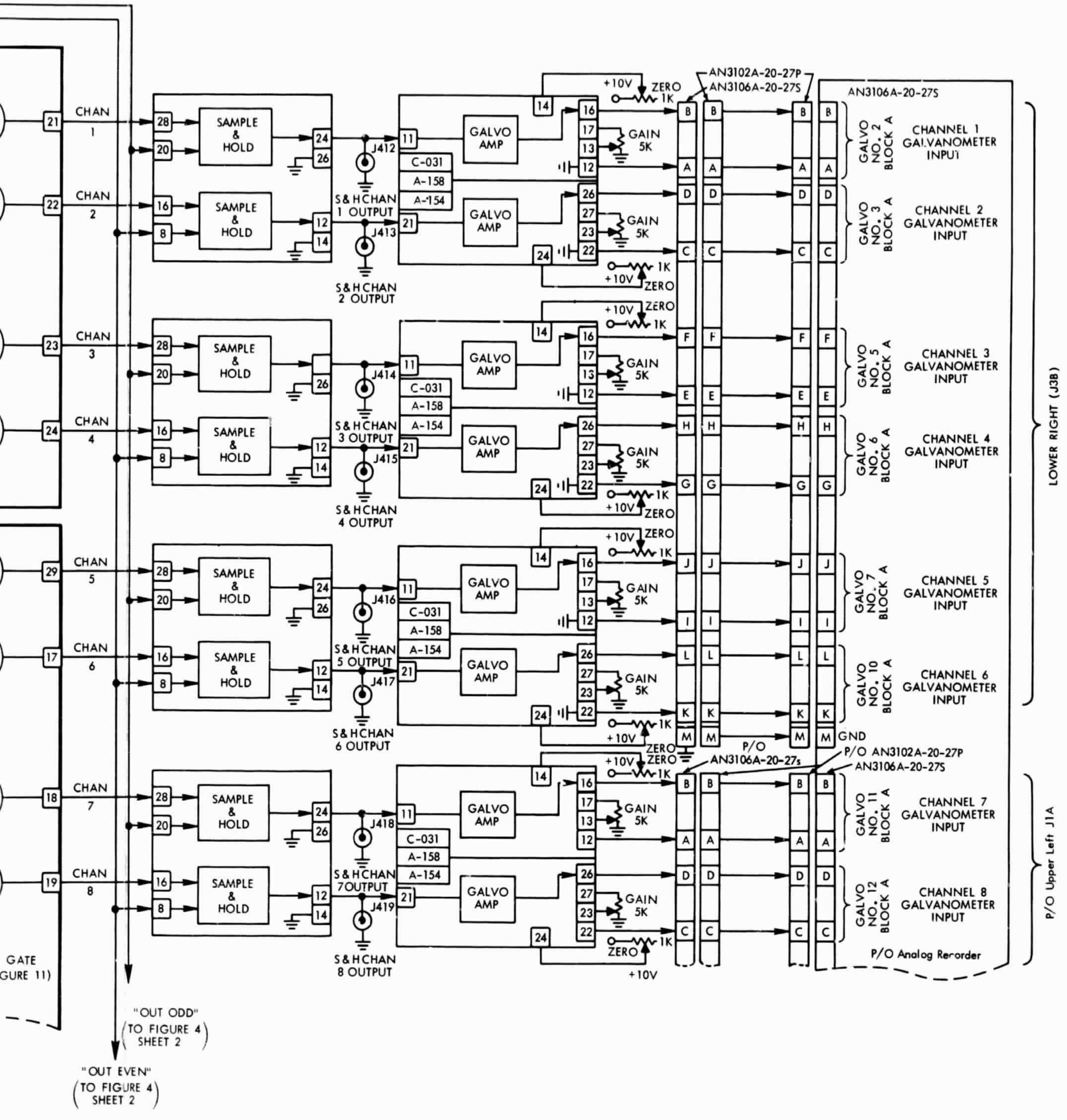


Figure 4. PPM to Analog Converter, Overall Block Diagram (Sheet 1 of 2)

FOLDOUT FRAME 2

PRECEDING PAGE BLANK NOT FILMED.

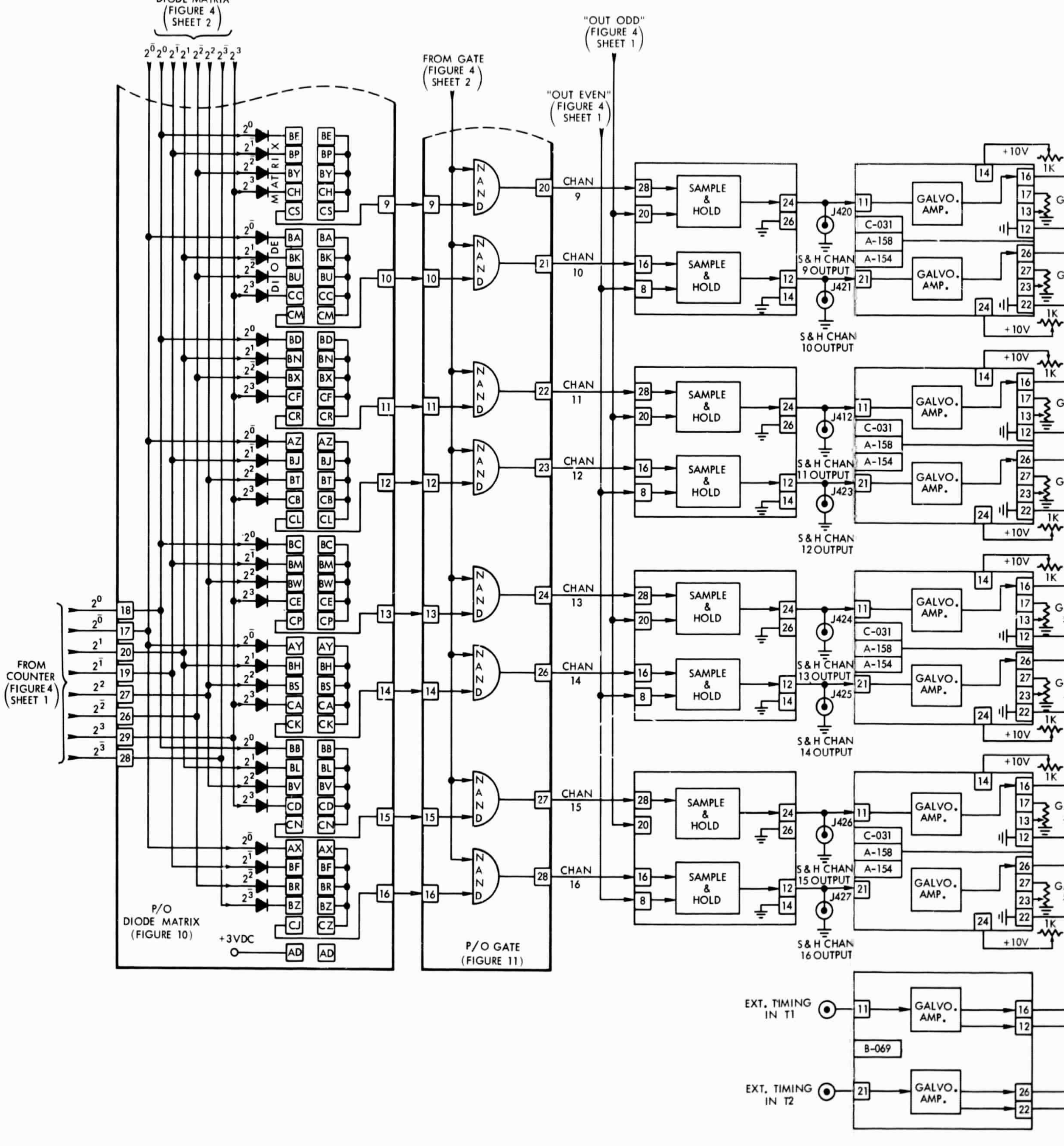
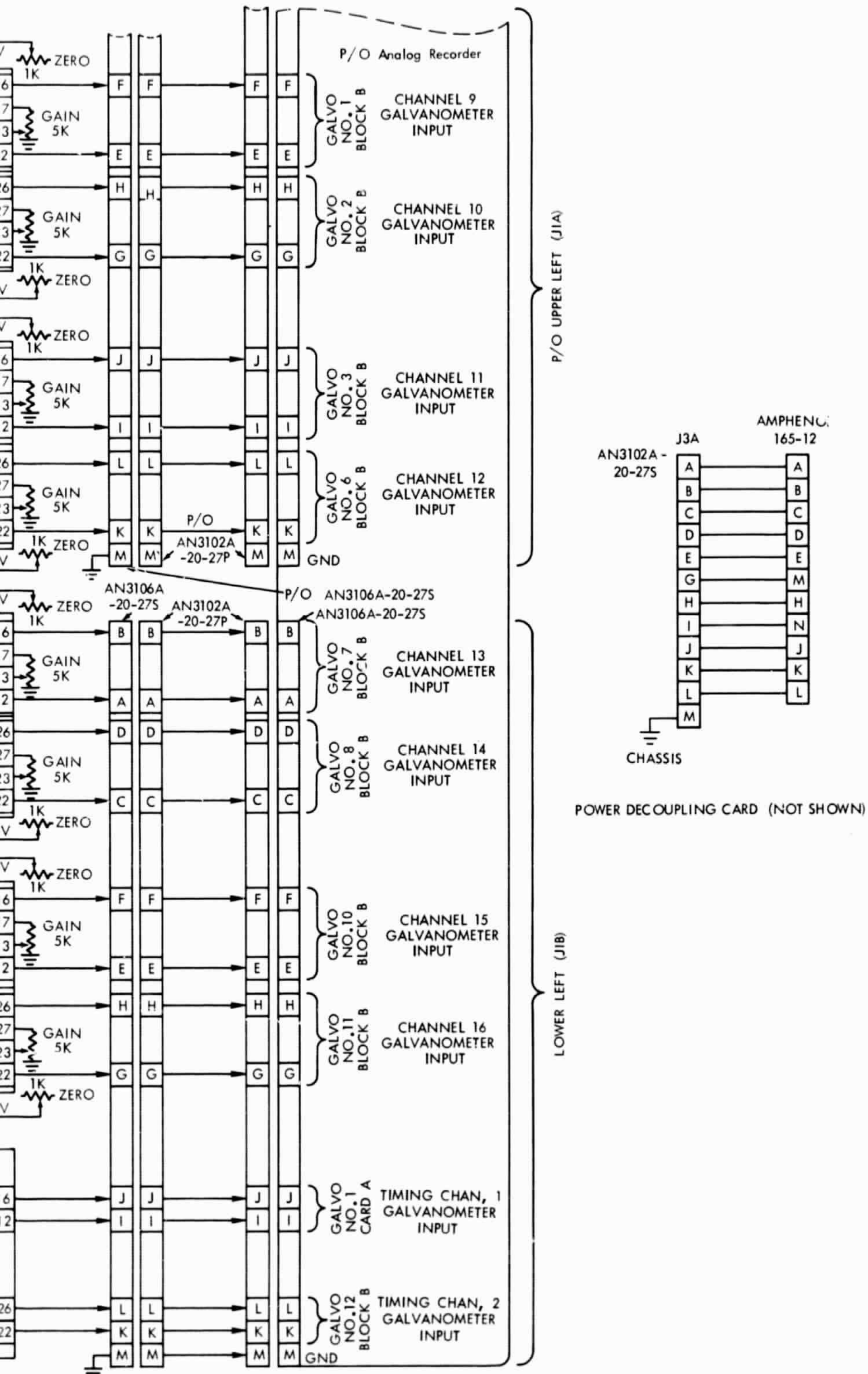


Figure 4

FOLDOUT FRAME



ure 4. PPM to Analog Converter, Overall Block Diagram (Sheet 2 of 2)

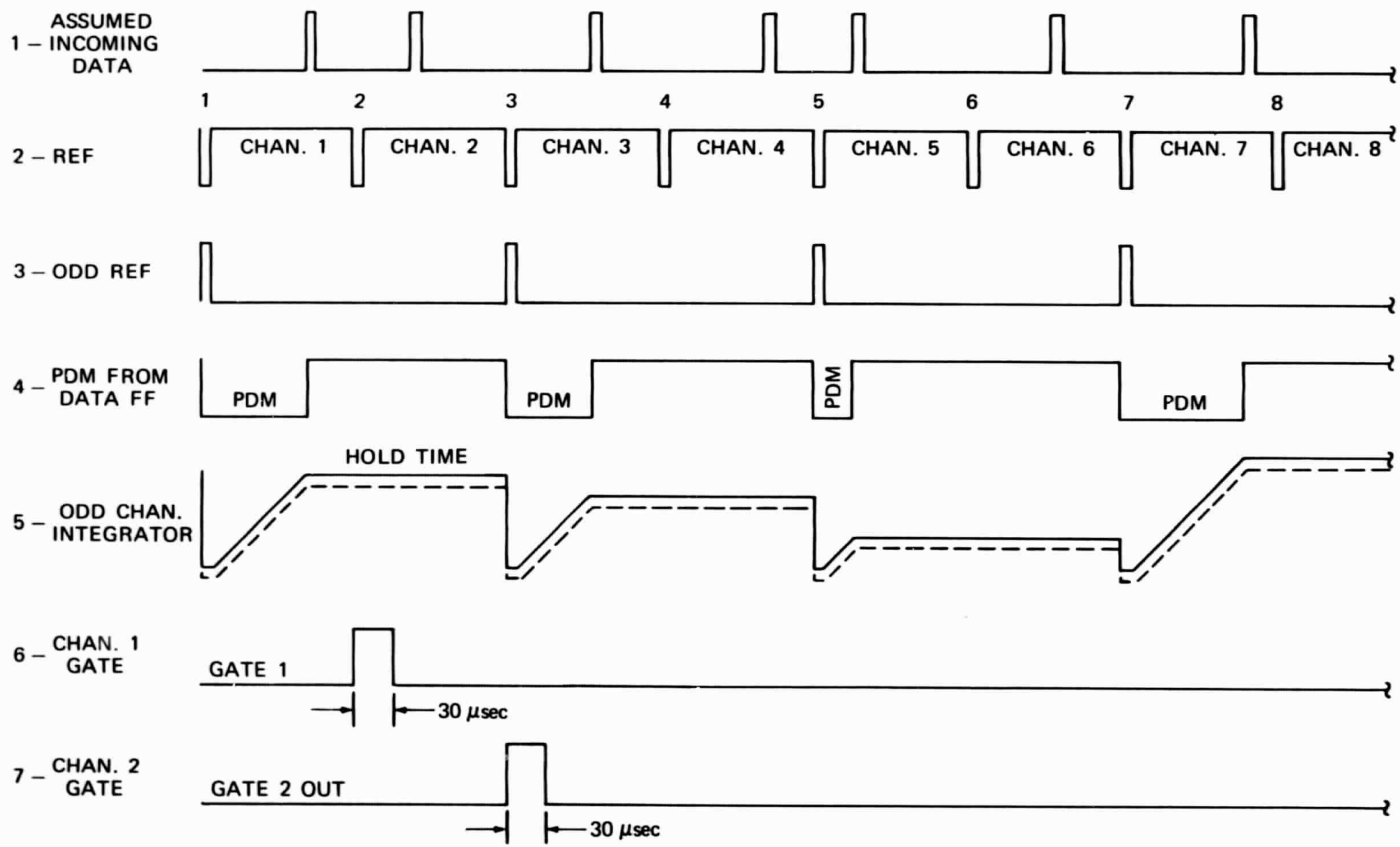


Figure 5. Integrator Waveforms

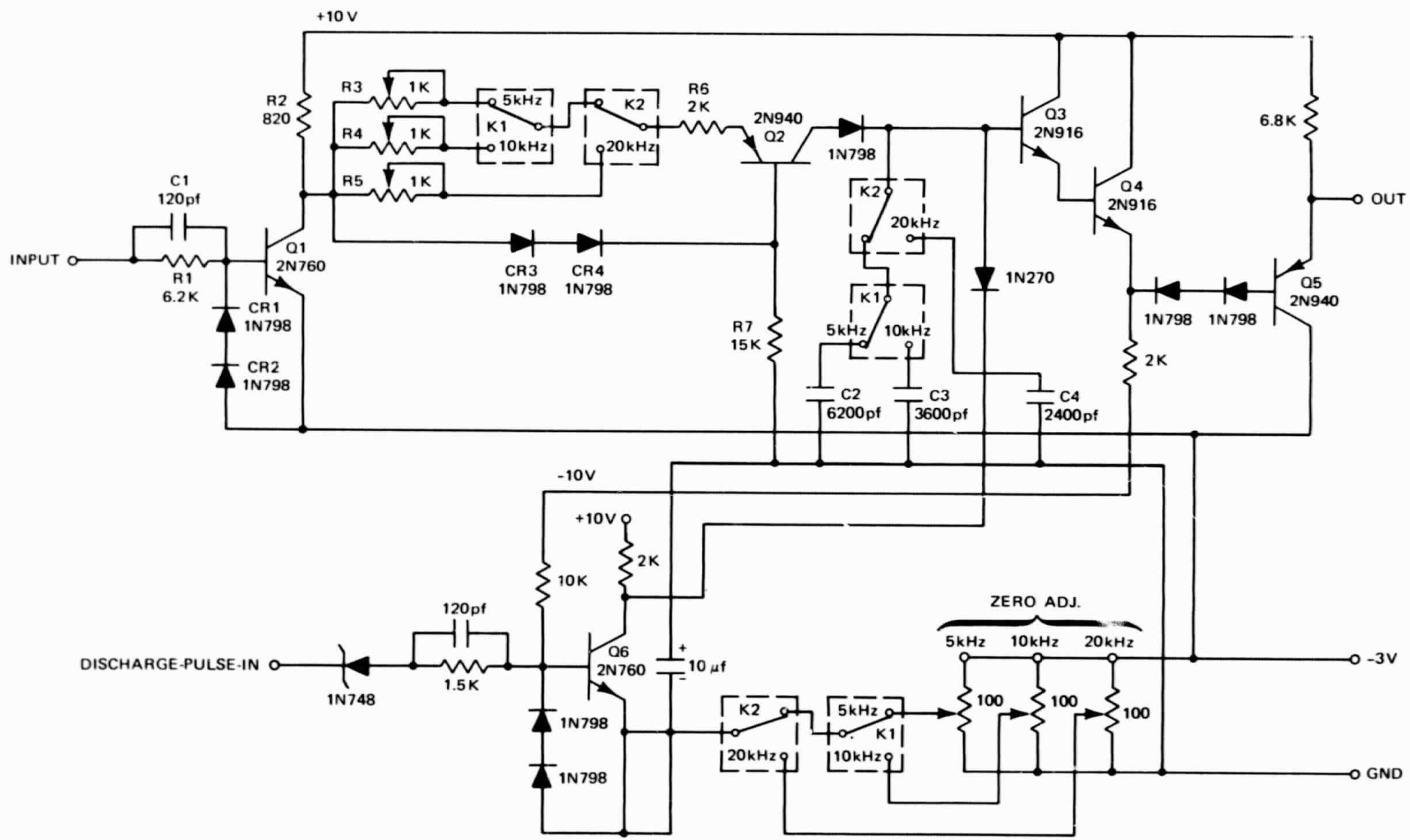


Figure 6. Integrator, Simplified Schematic Diagram

The PPM to Analog Converter also has the capability of programming various channel outputs through any chosen galvanometer, provided that even channel outputs are connected to even galvanometers, and odd channel outputs are connected to odd galvanometers. This is achieved by using a special connector in the diode matrix card, where the correct binary bits are shorted to give the desired channel. Each of these bits comes out to a particular single pin. Refer to the Operation section of this report for detailed channel programming instructions. Complete schematic diagrams of the PPM to Analog Converter are contained in the Maintenance section of this report. See page 20.

OPERATION

Assuming that the equipment is operable, these operating instructions cover daily procedures prior to any integration or real-time tests. The procedures ensure that all channels are calibrated (1-inch deflection for 5-volt input voltage), and also that timing is correctly recorded.

Perform the following steps:

1. Inspect the analog recorder for adequate paper supply.

NOTE

Full roll of paper is not required.

2. Check the power supply voltages to the analog recorder. Adjust as needed.

3. Turn on the record lamp.

NOTE

The fluorescent lamp is usally sufficient at this point, since most types of recording paper used are sensitive to this light.

4. Select 2 IN/SEC speed on the analog recorder.

5. On the patch panel, connect the output of the Simulator to the input of the Servo Clock, and the output of the Servo Clock to the input of the Analog to PPM Converter.

6. Make a short run, ensuring that all channels are calibrated from zero to 5 volts.

7. Inspect all channels, and all steps of each channel, to ensure that zero position and gain are correct.

8. Adjust each channel as needed, using the GAIN and ZERO controls located on the front of the PPM to Analog Converter.

9. Make another recording and ensure that all channels are calibrated correctly.

10. Turn on the time code generator, either the Hyperion Time Code Generator or the Countdown Clock, and ensure that timing is recorded correctly.

NOTE

Ensure that the Time Code Generator is reset.

11. If integration or real-time tests are not scheduled within 10 minutes, turn off the record lamp of the analog recorder until 5 minutes before the test.

NOTE

The record lamp is rated at 100 hours.

As stated in the Theory of Operation section of this report, the PPM to Analog Converter has the capability of programming various channel outputs through any chosen galvanometer, provided that even channel outputs are connected to even galvanometers and odd channel outputs to odd galvanometers. This is achieved by using a special connector in the diode matrix card where the correct binary bits are shorted to give the correct channel. Each of these bits comes out to a particular single pin. Table 2 shows the pins to be shorted to produce any one of the 16 channels. Table 3 shows the channel number, and the pin related to this channel, and the slot of the galvanometer where the channel terminates. Table 4 lists the connectors, located on the back of the PPM to Analog Converter, used to connect the channel outputs to the analog recorder galvanometers.

Table 2
Channel Programming

Channel No.	Connector Pins to be Tied Together in Order to Obtain Change in the Opposite Side
1	JTbk
2	DNxg
3	HSaj
4	CMwf
5	FRZi
6	BLVd
7	EPYh
8	AKUc
9	BE, BP, BY, CH
10	BA, BK, BU, CC
11	BD, BN, BX, CF
12	AZ, BJ, BT, CB
13	BC, BM, BW, CE
14	AY, BH, BS, CA
15	BB, BL, BV, CD
16	AX, BF, BR, BZ

Table 3
Channel Connections

Gate No.	Input Pin	Galvanometer Slot No.	
1	u	7	Left Block
2	q	8	
3	t	9	
4	p	10	
5	s	11	
6	n	12	
7	C	1	Right Block
8	M	2	
9	CS	3	
10	CM	4	
11	CR	5	
12	CL	6	
13	CP	7	
14	CK	8	
15	CN	9	
16	CJ	10	

Table 4
Output Connections

Channel	Channel Signal Voltage	Output Ground	Connector Location and Designation
1	B	A	
2	D	C	
3	F	E	Connector J3B (lower right)
4	H	G	
5	J	I	
6	L	K	
7	B	A	
8	D	C	
9	F	E	Upper Left J1A
10	H	G	
11	J	I	
12	L	K	
13	B	A	
14	D	C	
15	F	E	Lower Left J1B
16	H	G	
Timing 1 36 bit	J	I	
Timing 2 28 bit	L	K	

For normal operation, diode matrix pins JTbk are shorted to pin u, pins DNxg are shorted to pin q, and so on, so that all 16 channels come out of the analog recorder in sequence. See Figure 4. However, it is sometimes required to deviate from normal operation. For example, to place Channel 1 on the ninth galvanometer (on slot number 3 of the right block), pins JTbk (Channel 1) are shorted to the input of gate number 9, pin CS. As another example, to place Channel 4 on the twelfth channel galvanometer (on slot number 6 of the right block), pins CMwf (Channel 4) are shorted to pin CL, which is the input to gate 12.

MAINTENANCE

CALIBRATION

Assume that a new PPM to Analog Converter has been installed and must, therefore, be fully checked and calibrated. Perform the following steps:

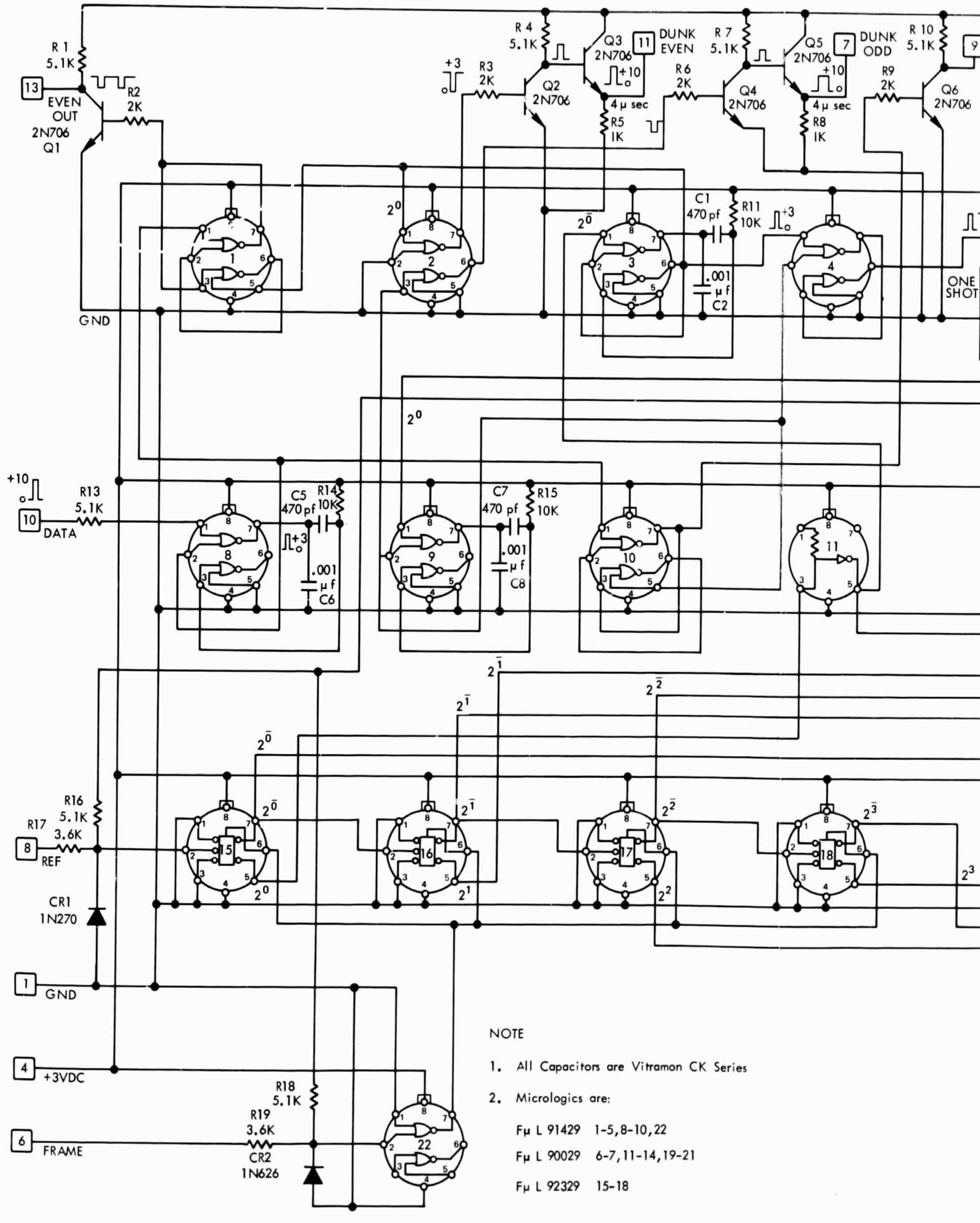
1. Using an oscilloscope, check inputs and outputs of the counter card. See Figures 2 and 7. The PPM format input should be frame, reference, and data pulses on pins 6, 8, and 10, respectively. Counter outputs appear on pins 17, 18, 19, 20, 26, 27, 28, and 29. The PDM format for odd and even channels appears on pins 9 and 13, respectively. The discharge pulses (Figure 8, Waveshapes A and B) on pins 7 and 11 should be of 4-microseconds duration and, finally, the output on pin 30 should be 30-microsecond negative pulses (Figure 8, Waveshape G).

NOTE

Steps 2 through 7 comprise the initial set-up of the integrator card.

2. With an oscilloscope or a voltmeter connected to pin 16, adjust the 5-kilohertz odd channel potentiometer, on the front panel, for a reading of -1 volt dc. Then with the oscilloscope or voltmeter connected to pin 17, adjust the 5-kilohertz even channel potentiometer for a voltage reading of -1 volt dc.

3. Change the ground station frequency from 5 to 10 kilohertz. Proceed as before, and adjust the 10-kilohertz potentiometers of odd and even channels for -1 volt dc on pins 15 and 18.



NOTE

1. All Capacitors are Vitramon CK Series

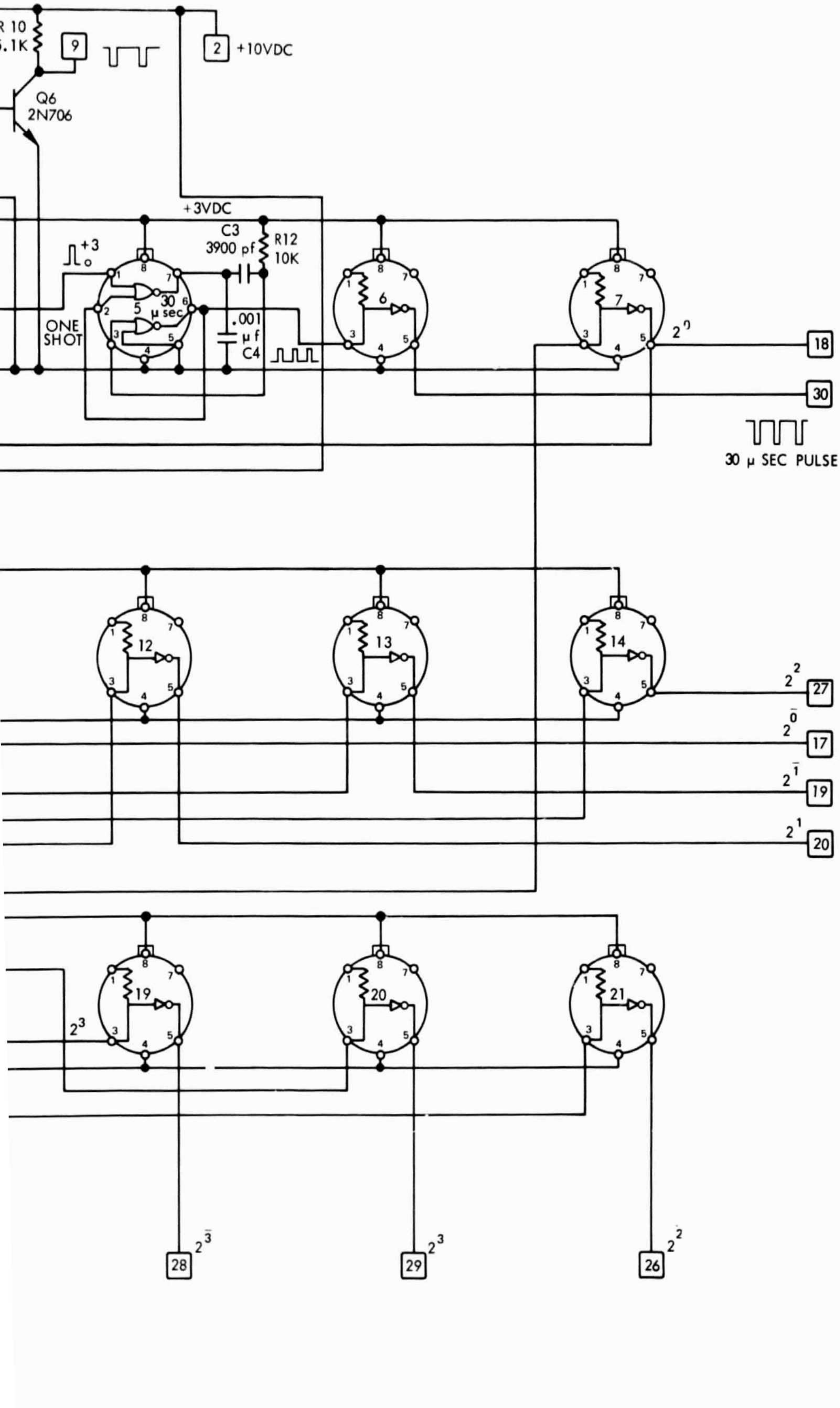
2. Micrologics are:

Fμ L 91429 1-5,8-10,22

Fμ L 90029 6-7,11-14,19-21

Fμ L 92329 15-18

FOLDOUT FRAME (



FOLDOUT FRAME 2 Figure 7. Counter Card 2, Schematic Diagram

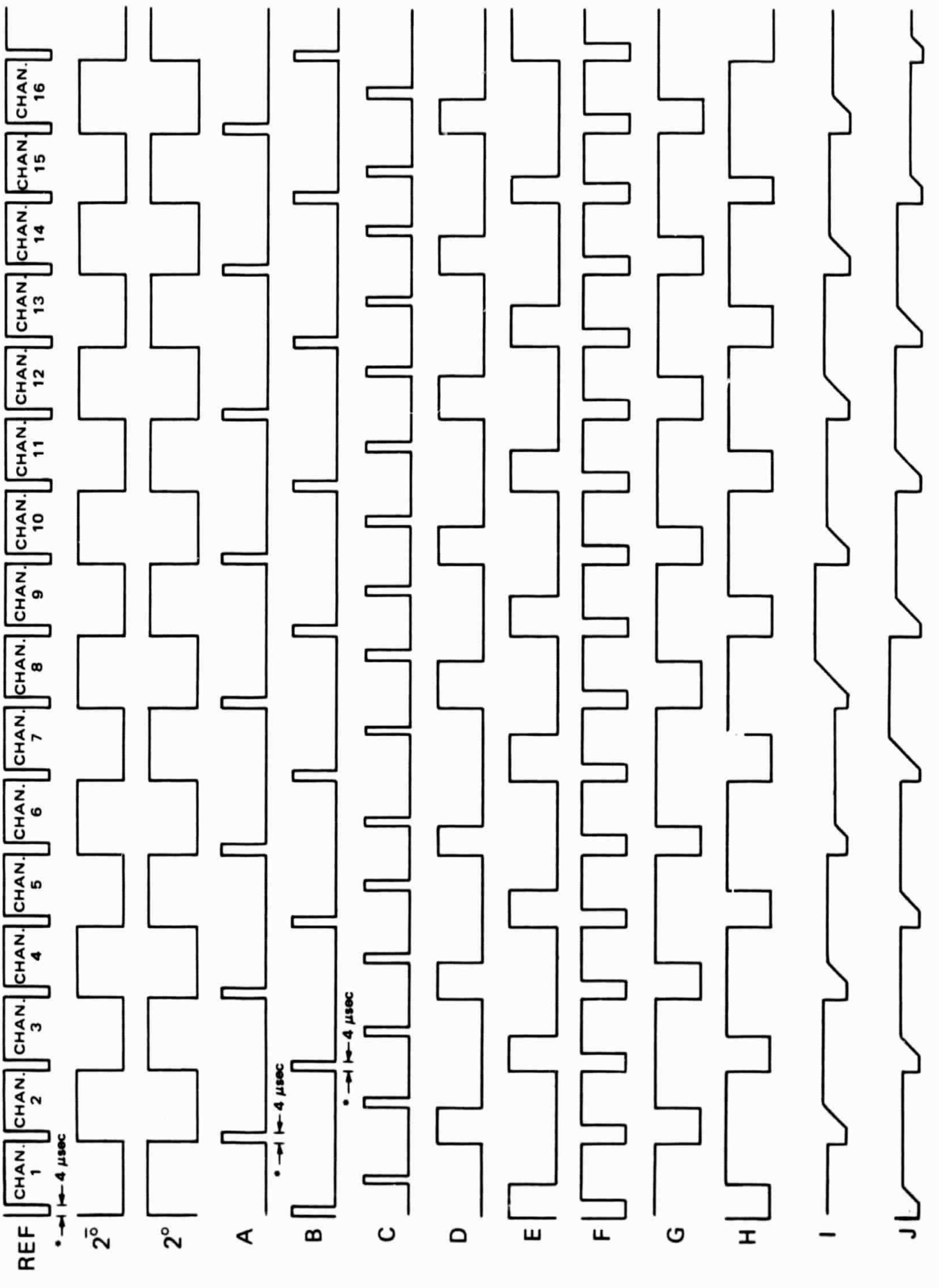


Figure 8. PPM to Analog Converter Waveforms

4. Change the ground station frequency from 10 to 20 kilohertz, and proceed as before by adjusting 20-kilohertz potentionmeters of odd and even channels for -1 volt dc on pins 14 and 19.

5. Using the Simulator, adjust the gain of the integrators, with the ground station frequency set at 5-kilohertz. See Figures 2 and 9. Looking on pin 26 of the integrator card, adjust odd channel potentiometer R4 of the integrator, so that the ramp function voltage varies as the data varies from zero to 5 volts dc. Next, adjust in the same way, integrator even channel potentiometer R14 whose output is on pin 24.

6. Change the ground station frequency from 5 to 10 kilohertz, and adjust R5 odd and R15 even integrator potentiometers as above.

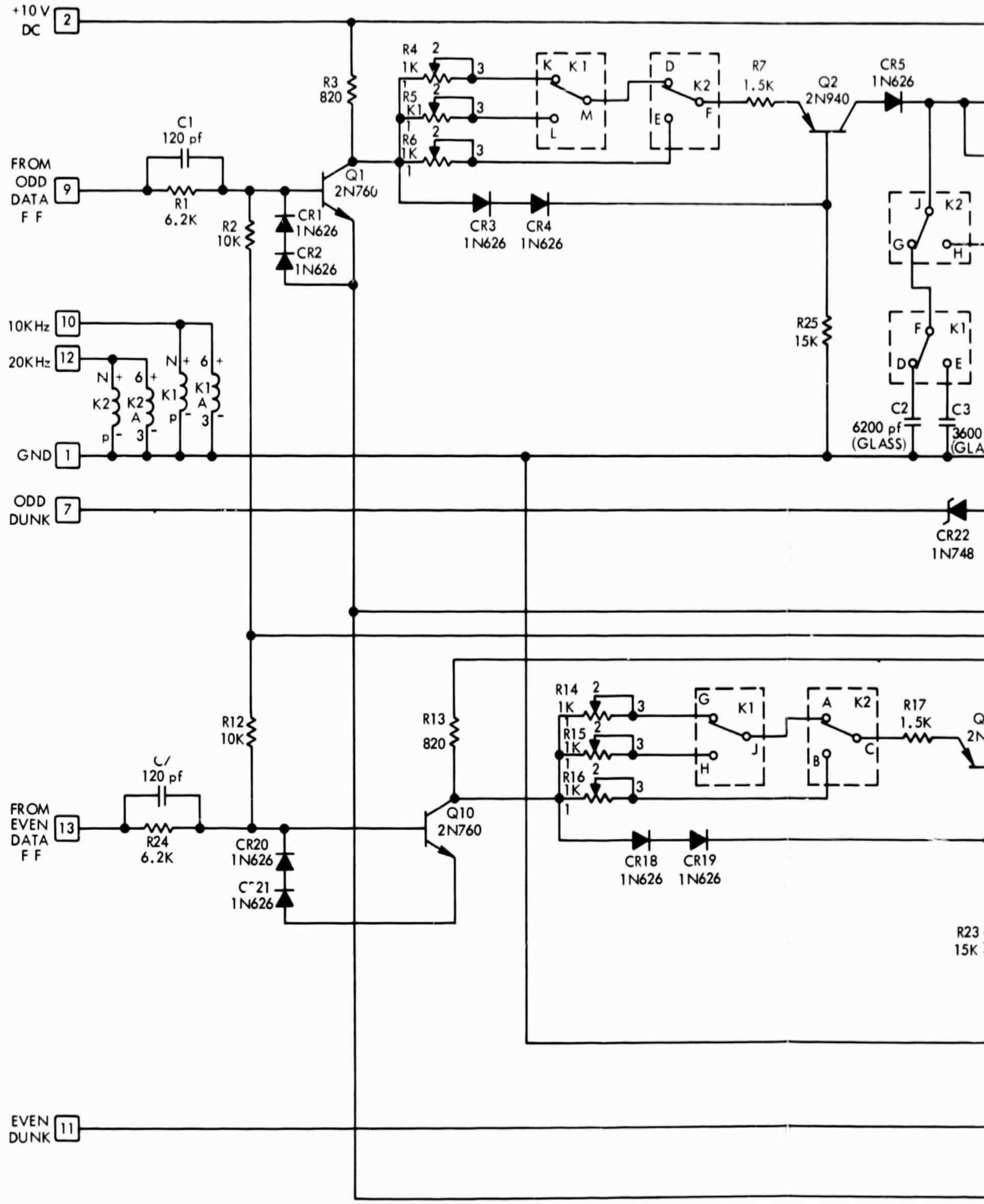
7. Change ground station frequency from 10 to 20 kilohertz, and adjust R6 odd and R16 even integrator potentiometers as above.

8. Check outputs of channel gates 1-16 on gating cards, and ensure that each gate output is a single positive pulse of 30 microseconds duration, occurring once every frame. See Figures 2, 10, and 11.

9. Check outputs, and the command-to-sample pulse of sample-and-hold cards, using an oscilloscope. Observe the outputs on pin 12, and the command-to-sample pulse on pin 16 (for odd channels) and on pins 24 and 28 (for even channels). See Figures 2 and 12. Outputs of sample-and-hold cards should be a dc voltage which varies as the data on the same channel of the Simulator increases or decreases. The command-to-sample pulses occur every 20 microseconds at a 5-kilohertz rate.

10. A final set-up of the integrator is made by viewing the output of the sample-and-hold card, Channels 3 and 4. Using a precision dc-voltmeter at the output of Channel 3 (odd), repeat steps 2 through 7. After the odd channels are adjusted, repeat steps 2 through 7 for even channels.

11. To check out the galvanometer driver-amplifier cards, first turn all of the front panel GAIN potentiometers fully counter-clockwise, and balance the collectors of transistors Q5 and Q6. See Figures 2 and 13. These collectors are brought out to two test points. Connect a voltmeter across these points and observe for zero volts. If Q5 and Q6 are not balanced, adjust balance potentiometer R10, located on the card, for zero volts on the dc voltmeter.



NOTES -

1. K1, K2 = BRANSON SRA-4C-12C
2. K1A, K2A = FILTOR DJ12C1P6A
3. R4, R5, R6, R14, R15, R16 = BOURNS 32 80P -1-102
4. C2, C3, C4, C8, C9, C10 = GLASS CAPACITORS.
5. C1, C5, C7, C11 = VITRAMON (CK TYPE)
6. C6, C12 = TANTALUM 47 μf 20 V

FOLDOUT FRAME 1

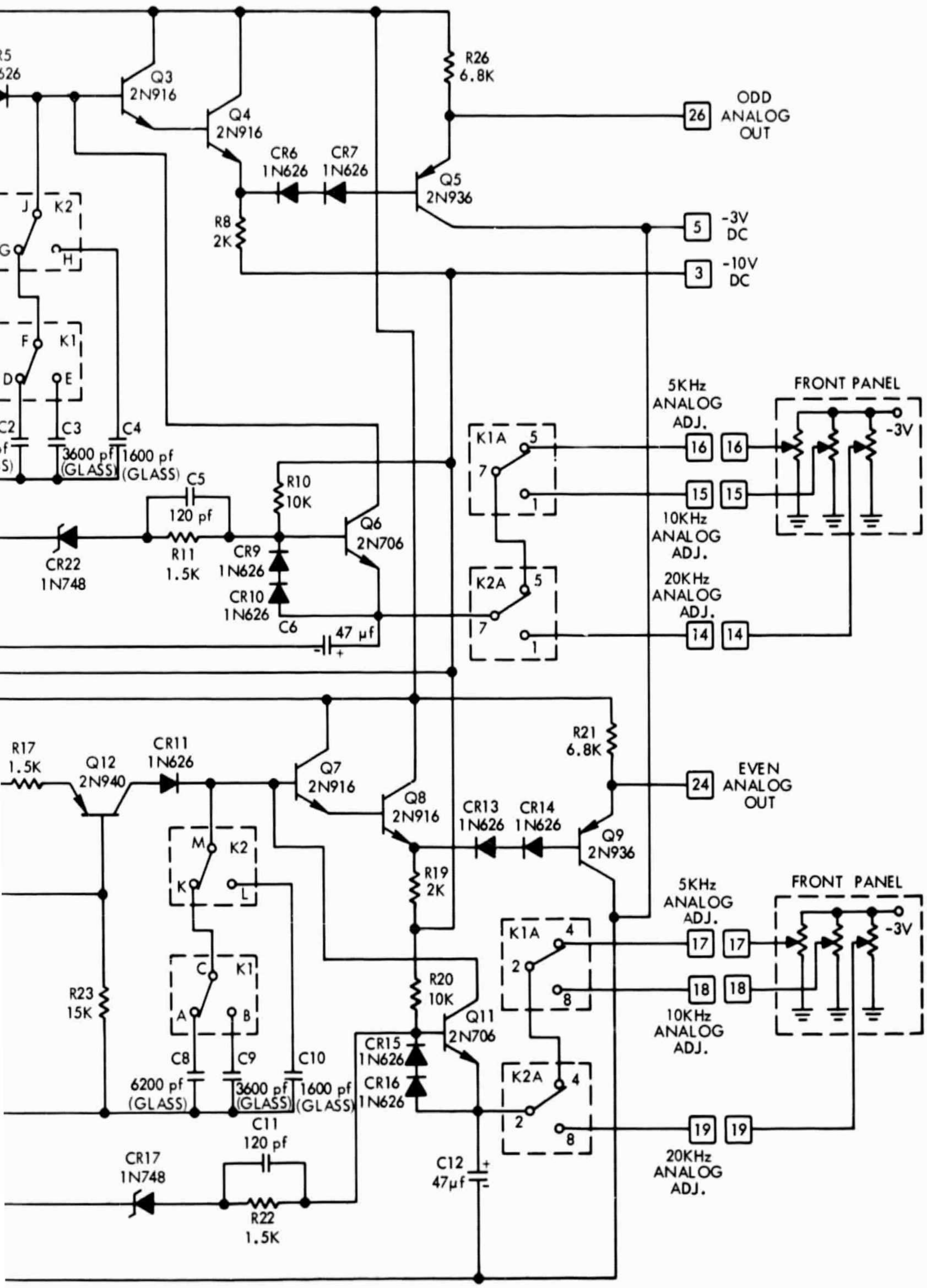
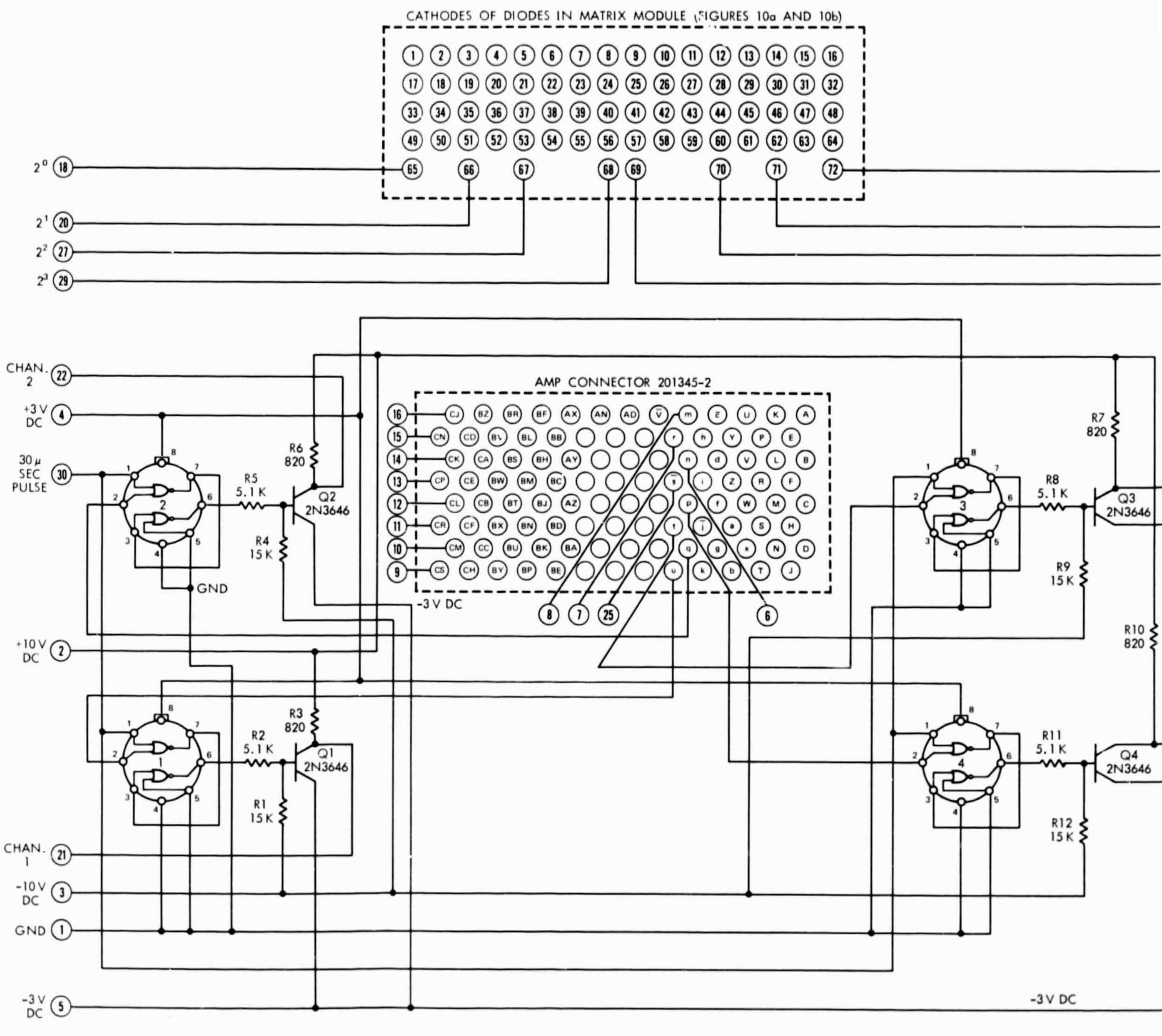


Figure 9. Integrator Card, Schematic Diagram

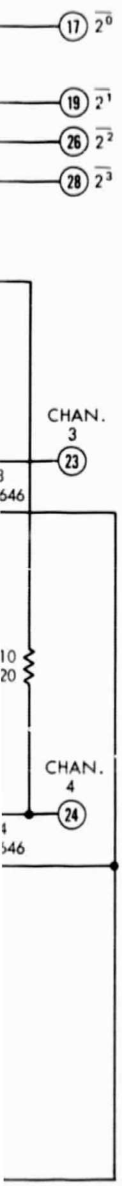
FOLDOUT FRAME 2

PRECEDING PAGE BLANK NOT FILMED.



FOLDOUT FRAME

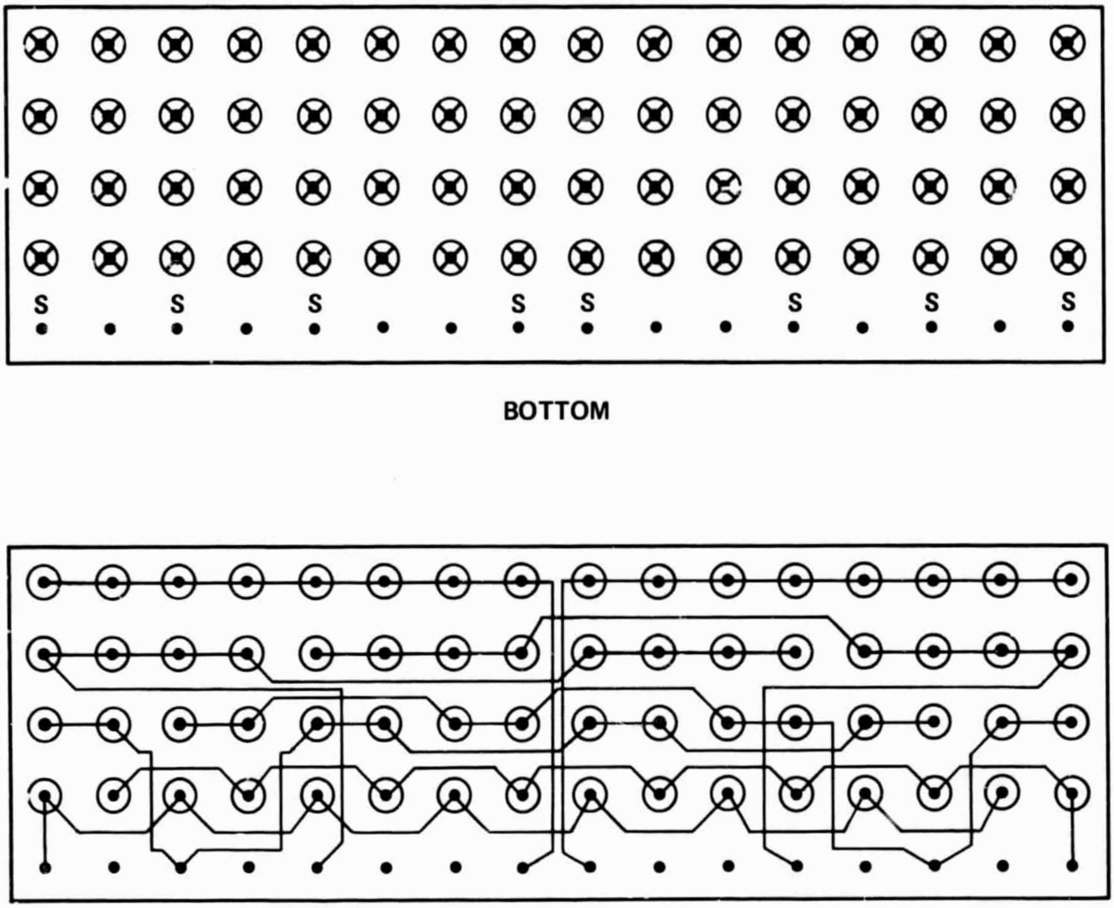
~~FOLDOUT FRAME~~



CONNECT DIODES TO CONNECTOR PINS AS SHOWN									
DIODE NO.	TO CONNECTOR PIN	DIODE NO.	TO CONNECTOR PIN	DIODE NO.	TO CONNECTOR PIN	DIODE NO.	TO CONNECTOR PIN	DIODE NO.	TO CONNECTOR PIN
1	CD	15	k	29	a	43	R	57	E
2	CA	16	BZ	30	x	44	M	58	B
3	CE	17	BV	31	b	45	S	59	F
4	CB	18	BS	32	BR	46	N	60	C
5	CF	19	BW	33	BL	47	T	61	H
6	CC	20	BT	34	BH	48	BF	62	D
7	CH	21	BX	35	BN	49	BB	63	J
8	$\bar{c}$	22	BU	36	BJ	50	AY	64	AX
9	h	23	BY	37	BN	51	BC		
10	d	24	U	38	BK	52	AZ		
11	i	25	Y	39	BP	53	BD		
12	f	26	V	40	K	54	BA		
13	$\bar{j}$	27	Z	41	P	55	BE		
14	g	28	W	42	L	56	A		

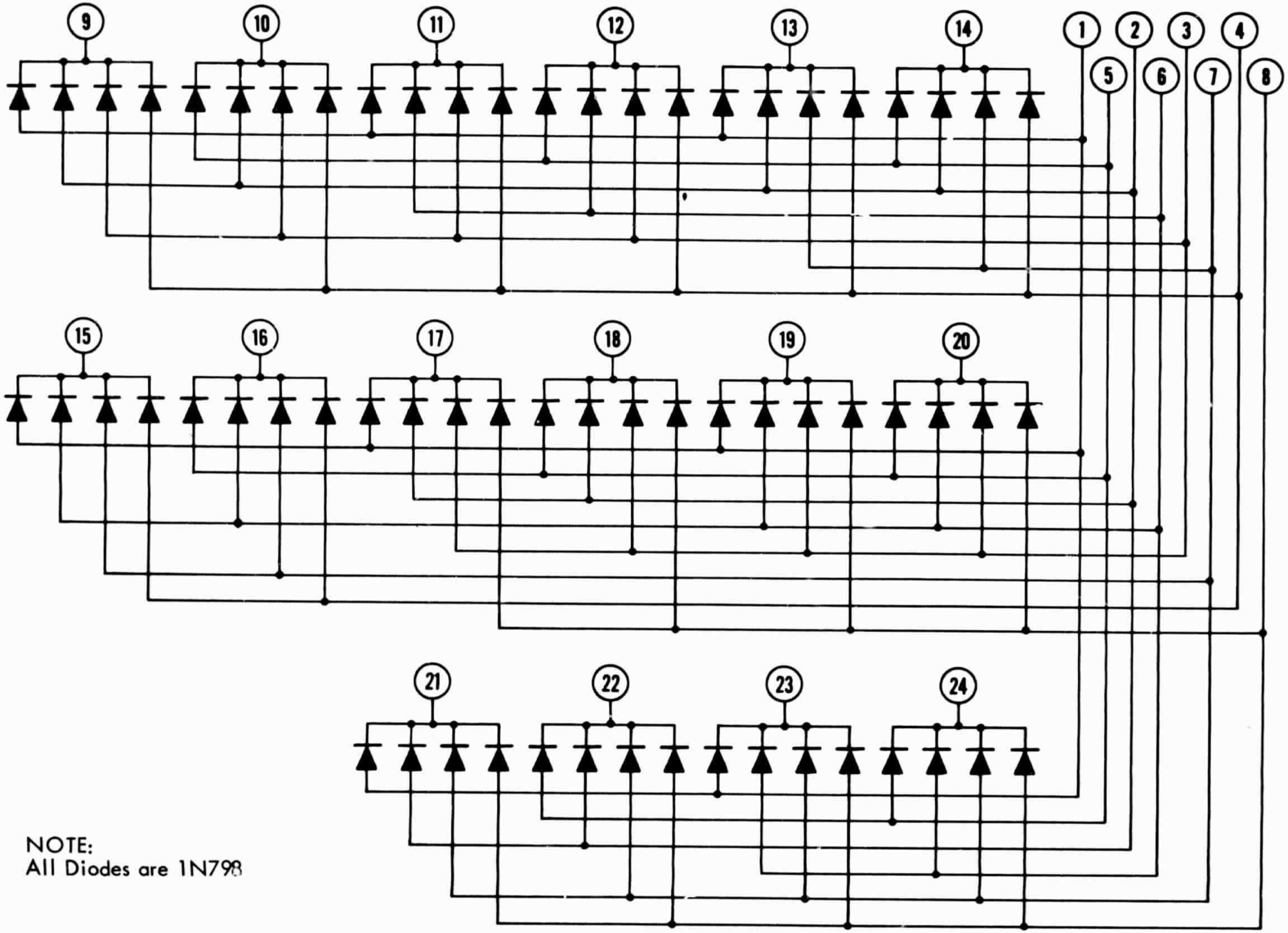
NOTE: MICROLOGICS 1-4 ARE FμL 91429

Figure 10. Patch Plug and Gate Decoder Card, Schematic Diagram



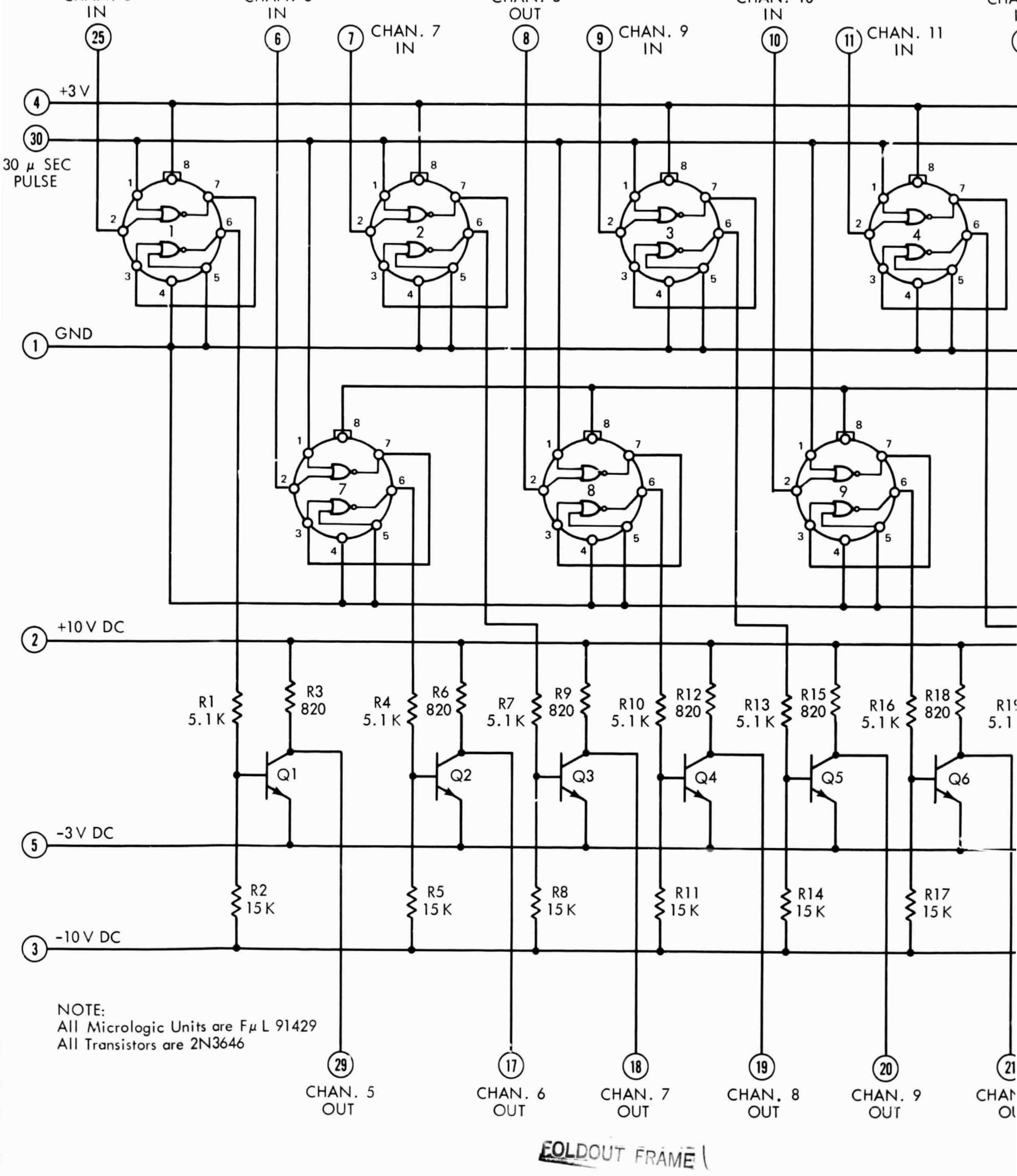
NOTE:
X = Output of Diodes to Channel Patch
S = Input to Diode Matrix

Figure 10a. Diode Matrix Layout



NOTE:
All Diodes are 1N798

Figure 10b. Diode Matrix, Diode Layout



NOTE:
All Micrologic Units are FμL 91429
All Transistors are 2N3646

FOLDOUT FRAME 1

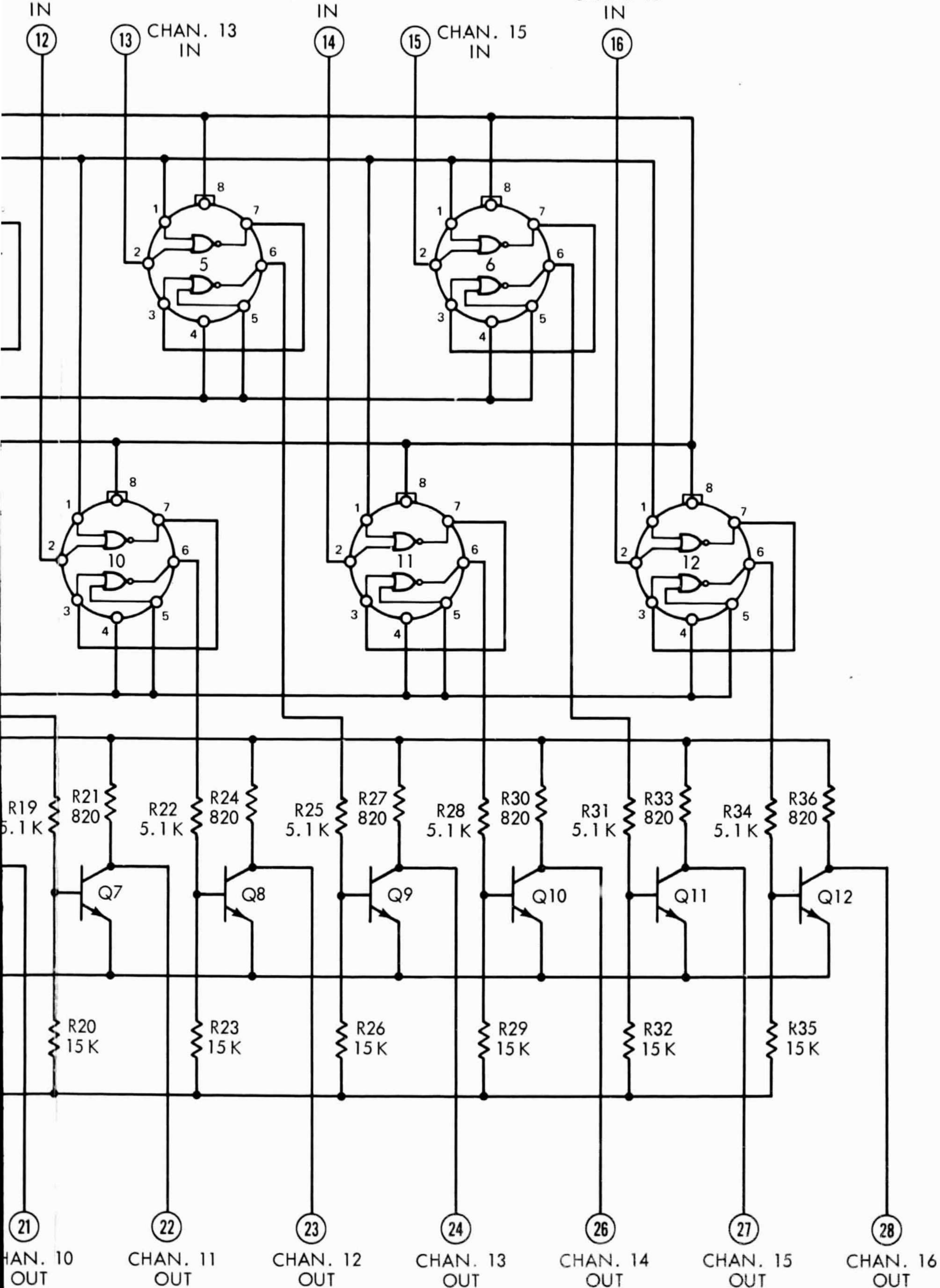
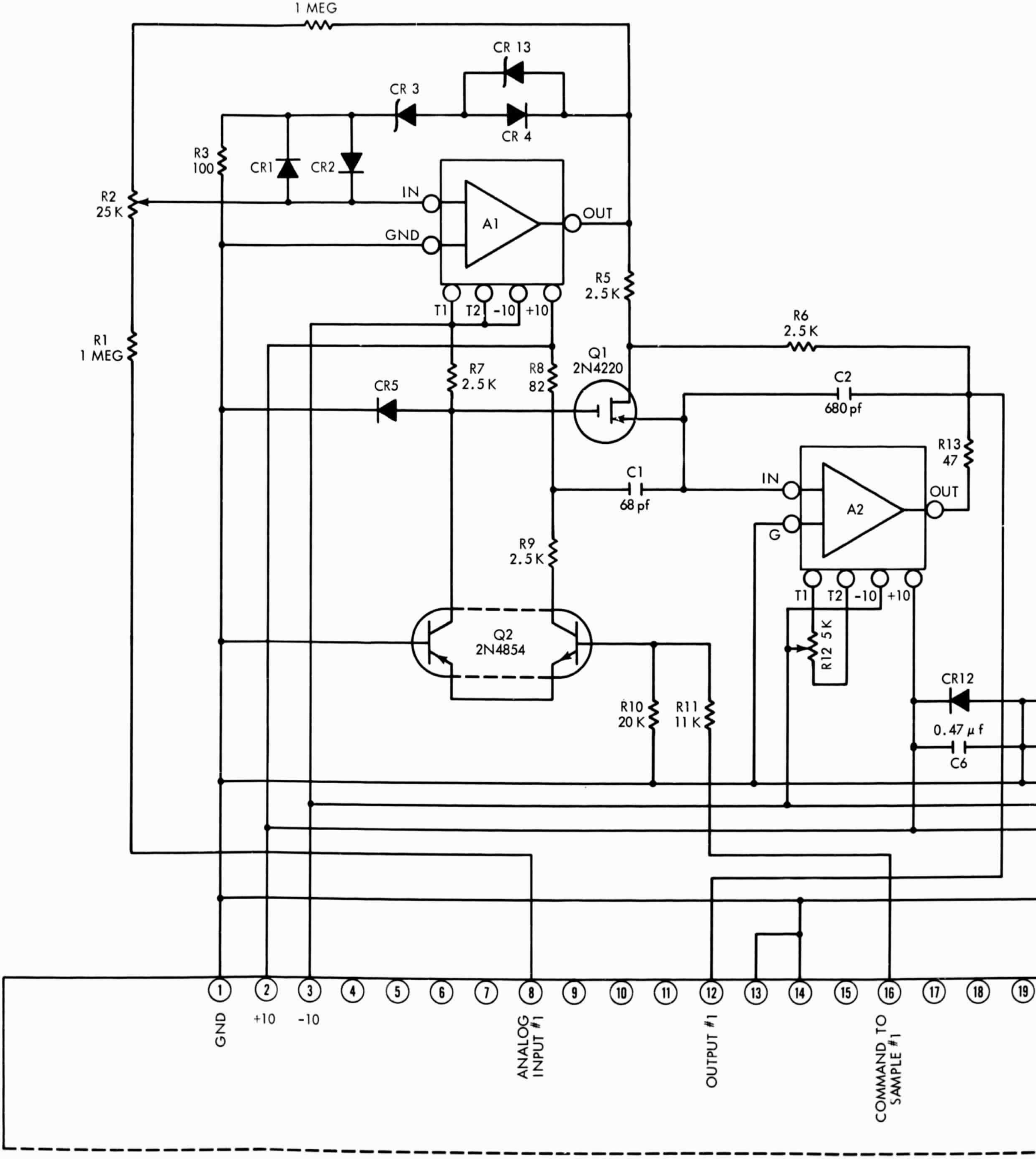


Figure 11. Gate Card, Schematic Diagram

FOLDOUT FRAME 2



FOLDOUT FRAME

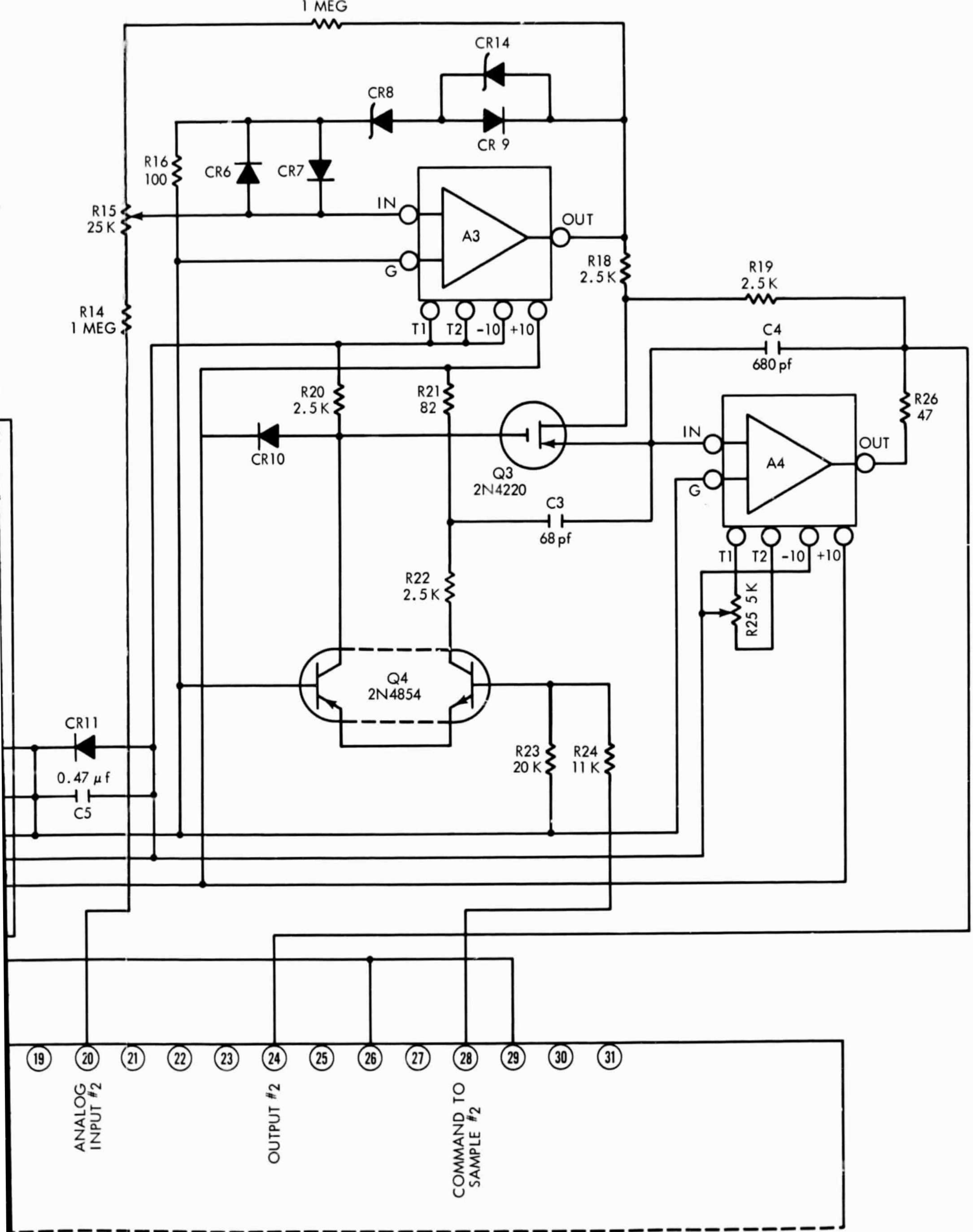
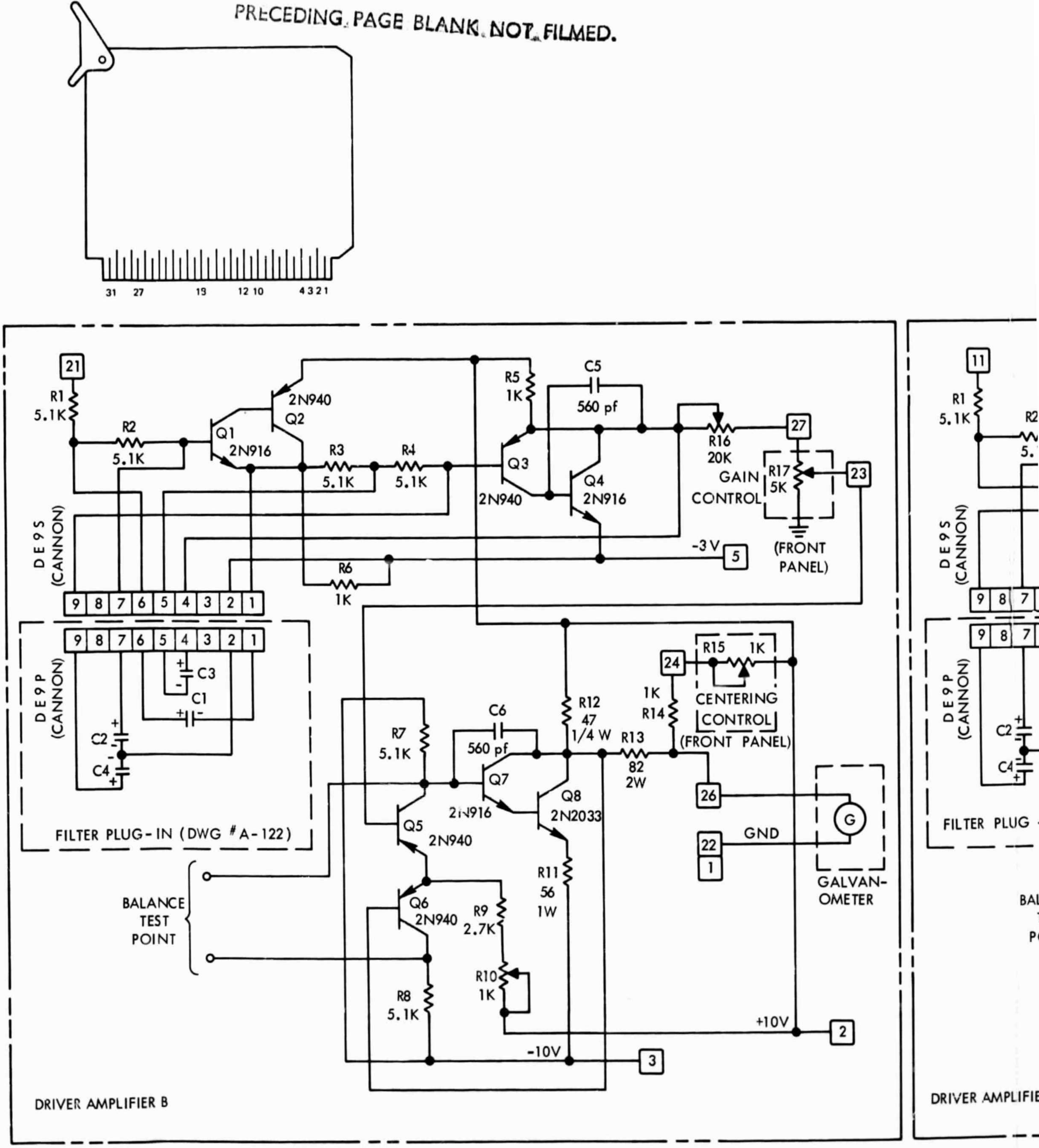


Figure 12. Sample and Hold Circuit, Schematic Diagram

PRECEDING PAGE BLANK NOT FILMED.



FOLDOUT FRAME 1

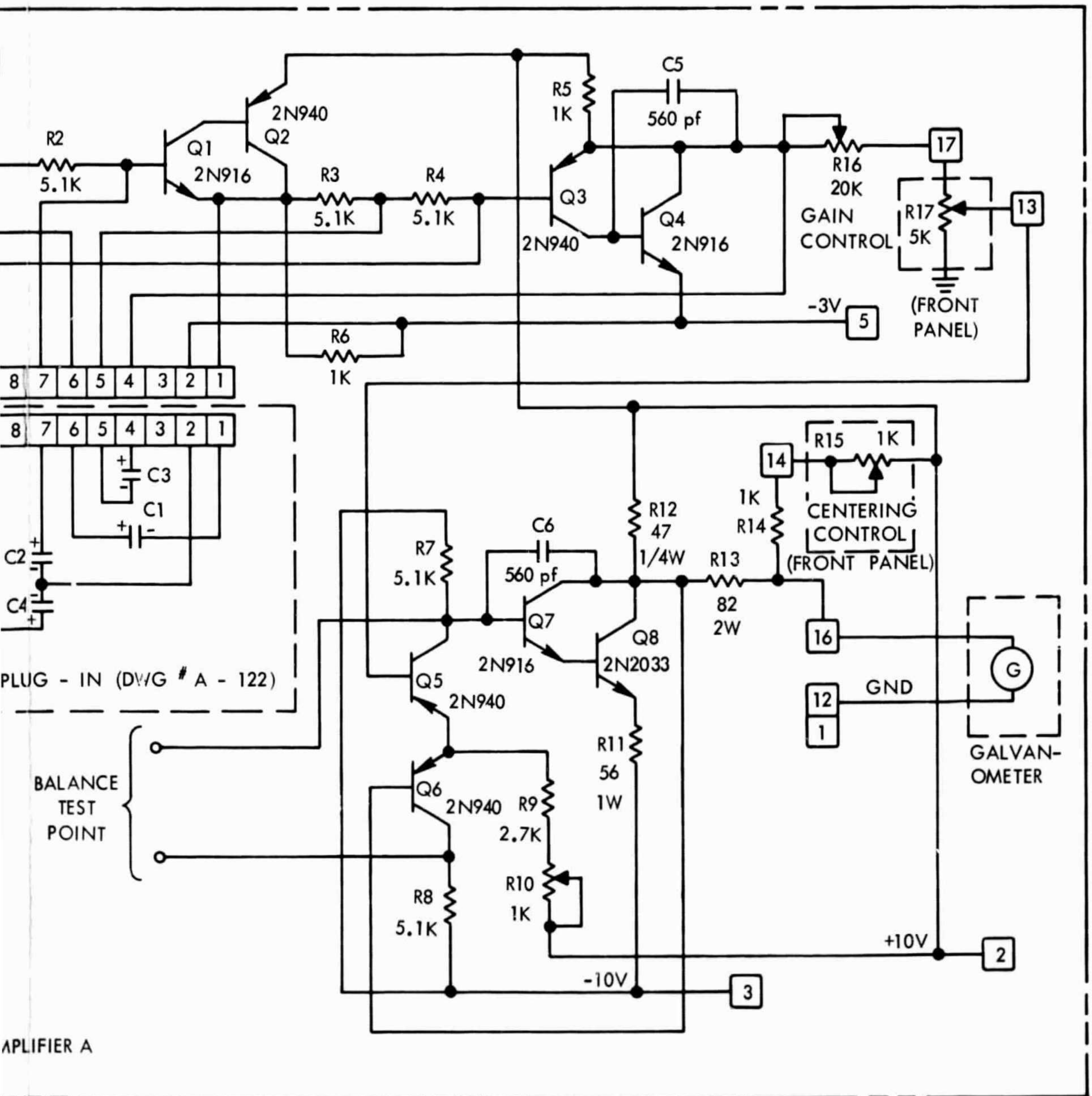


Figure 13. Galvanometer Driver Amplifiers, Schematic Diagram

FOLDOUT FRAME 2

NOTE

Before the gain potentiometers are adjusted, ensure that the galvanometers are positioned correctly in the analog recorder.

12. Set all channels of the Simulator to zero volts. Before aligning the galvanometers of the analog recorder to zero position for all 16 channels, check that the ZERO potentiometers, on the front panel, are centered to ensure flexibility of a fine adjustment in both directions.

13. With all galvanometers aligned, turn the GAIN potentiometer on the front panel fully clockwise. Starting from Channel 1, adjust gain potentiometer R16, on the card, so the galvanometer spot deflects 2 inches when Simulator data varies from zero to +5 volts dc. See Figure 13. Adjust all 16 amplifiers in this way. This adjustment will change the zero position of these galvanometers, so realign the galvanometers.

14. Since maximum 2-inch deflection of the galvanometers is not necessary, adjust the GAIN potentiometers, on the front panel, for 1-inch deflections with 5 volts input data.

NOTE

When using the Airtronics Sample-and-Hold Unit, step 15 is applicable.

15. At this point make the final adjustments. The integrator card must again be precisely adjusted for all frequencies. Instead of using an oscilloscope, observe the galvanometer deflection. To do this, use the 5-kilohertz zero position and deflection, which corresponds to 5 volts data, of all galvanometers as a base. Change the station frequency to 10 kilohertz and adjust the front panel 10 kilohertz potentiometers of odd and even channels, so the zero position of the galvanometer bright spot coincides with that of the 5 kilohertz station frequency.

NOTE

Comparison is made by changing the frequency from 5 to 10 kilohertz, and back.

Adjust the gain at 10 kilohertz for 5 volts input data to coincide with that of 5 kilohertz for 5 volts input data. A visual indication is obtained by observing positions of galvanometer spots for 5 and 10 kilohertz. Next, calibrate the system the same way at 20-kilohertz station frequency.

In addition to the galvanometer amplifiers that are used for data channels, there are two amplifiers used to drive the timing galvanometers. See Figures 2 and 14. The two timing codes are the 36 and 28-bit NASA time codes, referred to on Figures 3, 4, and 15 as T1 and T2, respectively. Timing 1 and 2 galvanometers are located at the far right side of the analog recorder, in slots 11 and 12 of the right block. These two galvanometers are adjusted so that only the tops of the binary pulses appear on the recording paper.

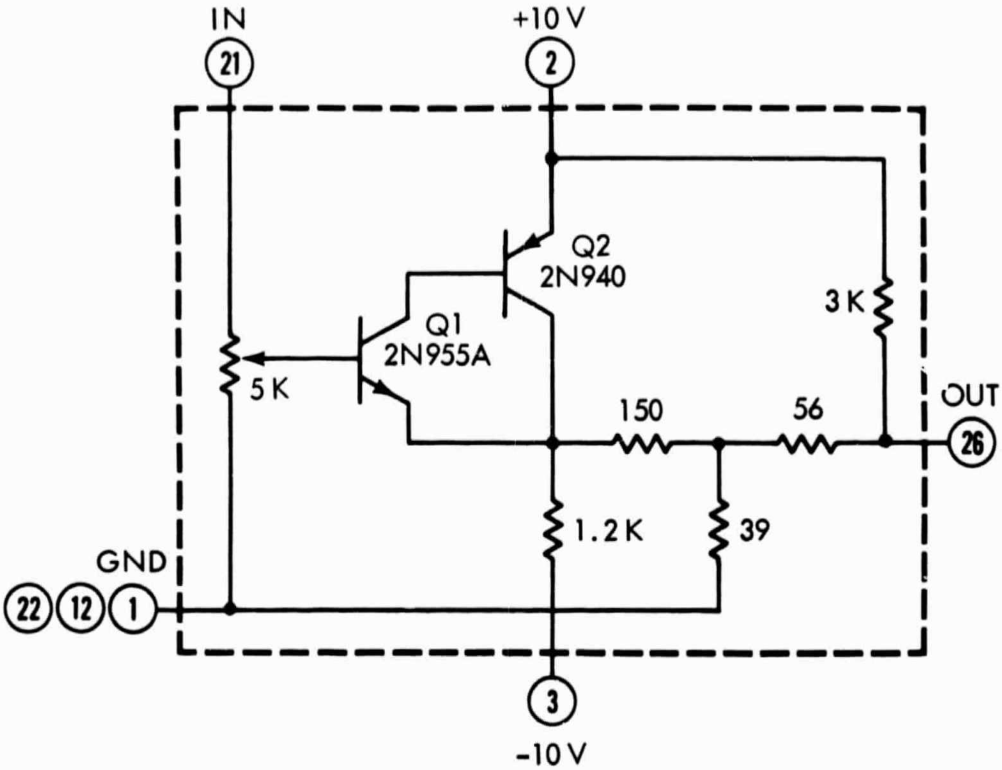
On the left side of the left block are the first six galvanometers used to record the countdown time-clock in decimal format. Once these galvanometers are aligned, no additional adjustment will be required.

NOTE

Before recording, ensure that the 82-ohm, 1/2-watt, 5-percent damping resistors are installed for the first six galvanometers. For location of the damping resistors, see Page 5-11, paragraph C of the manufacturer's manual.

PREVENTIVE MAINTENANCE

Preventive maintenance consists of general cleaning and periodic visual inspection. Accumulation of dust, dirt, grit, and/or grease on circuit boards is harmful, and should be guarded against by periodic inspection and cleaning. Every three to six months, visually inspect the equipment for signs of deterioration, loose connections, security of mounting, and foreign matter. The period between cleanings depends on the particular operating environment, and should be determined by visual inspection. As necessary, clean with a soft brush or low air pressure, being careful not to damage printed circuitry.



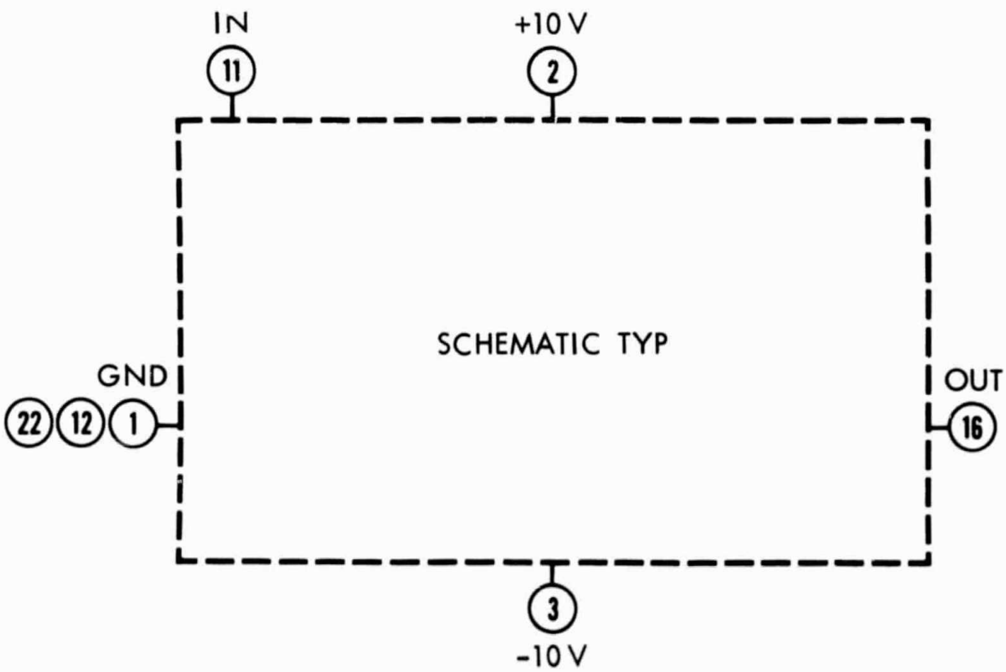
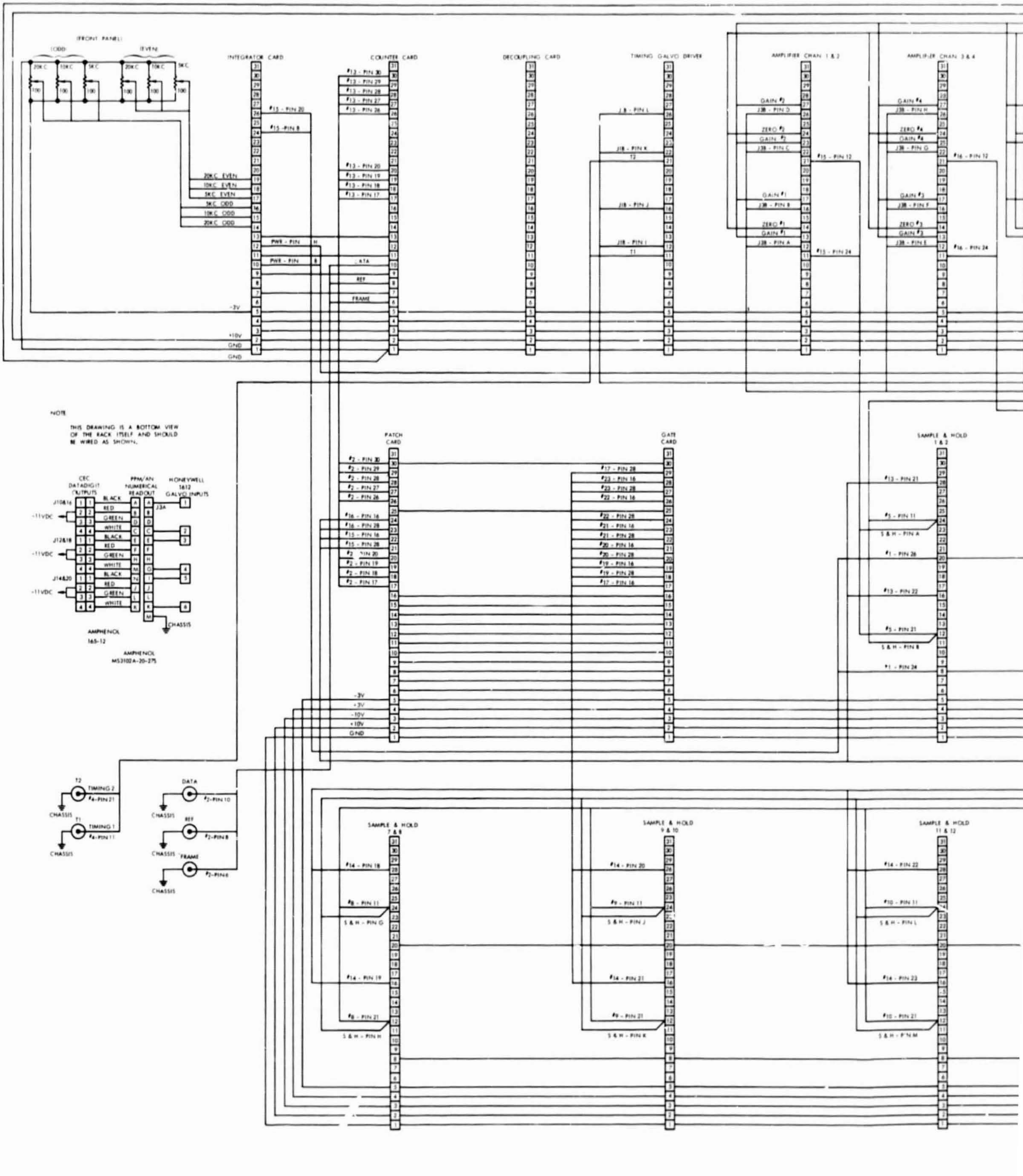
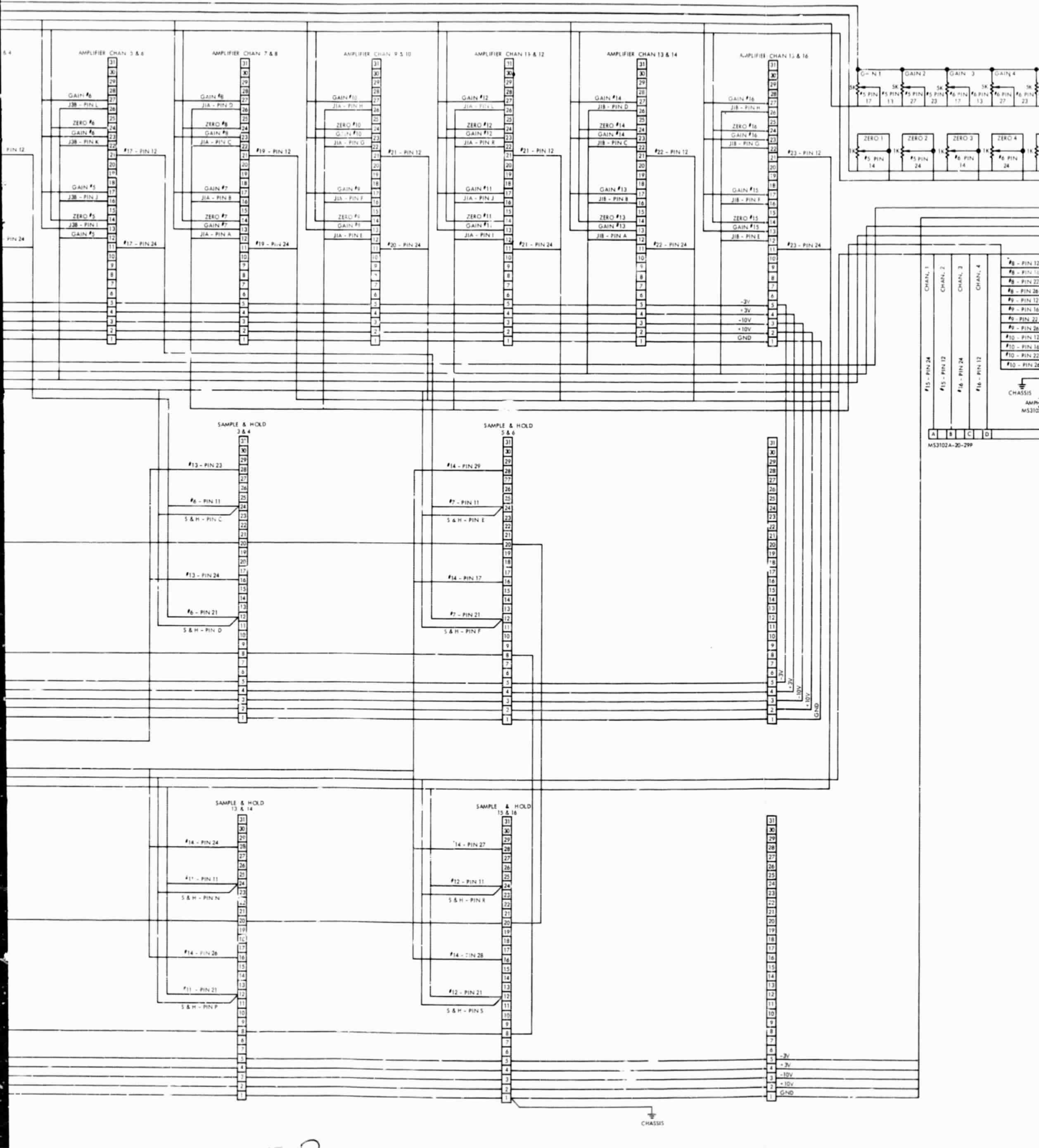


Figure 14. Timing Channels Galvanometer Driver Amplifier, Schematic Diagram

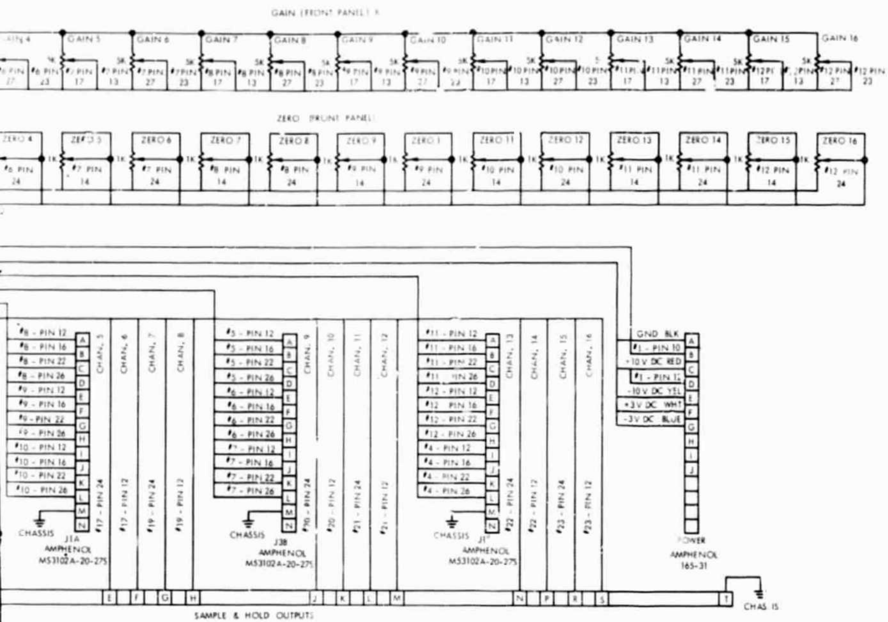
PRECEDING PAGE BLANK NOT FILMED.

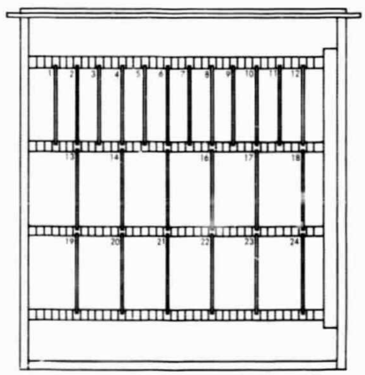


FOLDOUT FRAME



FOLDOUT FRAME 2





CARD ORIENTATION
(BOTTOM VIEW OF RACK)

CARD NO.	CARD	ASSY	SCHEMATIC	Figure
1	INTEGRATOR CARD	D-187	C-187	9
2	COUNTER CARD	D-164	C-186	7
3	DECOUPLING CARD	C-276		4
4	TIMING GALVO DIVER	D-148	B-069	14
5	AMPLIFIER CHAN 1&2	D-072	C-123	12
6	AMPLIFIER CHAN 3&4	D-072	C-123	
7	AMPLIFIER CHAN 5&6	D-072	C-123	
8	AMPLIFIER CHAN 7&8	D-072	C	
9	AMPLIFIER CHAN 9&10	D-072	C-123	
10	AMPLIFIER CHAN 11&12	D-072	C-123	
11	AMPLIFIER CHAN 13&14	D-072	C-123	
12	AMPLIFIER CHAN 15&16	D-072	C-123	
13	PATCH CARD		C-188	10
14	GATE CARD	D-163	C-185	11
15	SAMPLE & HOLD 1&2		D-182	12
16	SAMPLE & HOLD 3&4		D-182	
17	SAMPLE & HOLD 5&6		D-182	
18	BLANK			
19	SAMPLE & HOLD 7&8		D-182	12
20	SAMPLE & HOLD 9&10		D-182	
21	SAMPLE & HOLD 11&12		D-182	
22	SAMPLE & HOLD 13&14		D-182	
23	SAMPLE & HOLD 15&16		D-182	
24	BLANK			
	PATCH CONNECTOR	A-110	A-110	

Figure 15. PPM to Analog Converter, Wiring Diagram

CORRECTIVE MAINTENANCE

Figure 15, the wiring diagram, is provided as a general aid for troubleshooting. Before attempting the repair of circuit boards suspected of malfunction, verify that the sympton is not caused by malfunction of associated equipment such as the mounting case or inter-unit cabling. Once the existence of a defective plug-in module or circuitboard has been established, visually inspect it for obviously damaged components such as burned resistors. Next, ensure that the correct operating power is applied to the case and that the power supply potentials are correct.